ВВС

SPECIAL REPORT: How music heals the injured brain



PLUS: Are we living in a simulation?

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THE BACK-UP PLAN THAT COULD SAVE OUR PLANET



Surprising facts your face reveals about you

DISCOVER

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- HOW BIG AN ANIMAL CAN GET
- WHY WE HAVE WISDOM TEETH



RICHARD DAWKINS ON:

BIO-BRICK BREAKTHROUGH Evolution, aliens and hatemail | Printed cells that build like Lego

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WELCOME



EARTH IS ON the brink of a mass extinction. The planet is losing species 100 times faster than would naturally be expected, and the cause of the problem is clear: us. And while other flora and fauna will be the first to suffer, it isn't clear how humans will adapt to such a cataclysmic event. The crops we eat, the water we drink and the air we breathe are so wired into the planet's ecosystems, that it's difficult to see how we might survive. But there's hope: conservation of our remaining natural resources could yet save the day. That's why seed vaults and gene

banks around the globe are stockpiling seeds, sperm and ova from the natural world. Turn to p38 to find out how this backup plan is taking shape.

Physicists, meanwhile, are busy creating worlds of their own. Durham University now houses one of the biggest and most powerful simulations of the Universe yet. With it, astronomers are able to pick apart the origins of the cosmos like never before – and hopefully uncover some of the mysterious properties of dark matter. Find out more on p61.

We also look at a subject close to my heart: music. I only ever achieved a grade 5 in piano, but I've never doubted the power of a great melody. Now psychiatrists and physicians alike are discovering that music can be medicine. Discover more on p52.



Daniel Bennett, Acting Editor

PS Don't miss our November issue, on sale 15 October 2015

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THIS MONTH WE...



...went to the launch of Project MC2, a new range of STEM-inspired dolls for children, and got to try out a geek chic photo booth. Read about the dolls on our website at bit.ly/projectmc2

...drove a hybrid SUV around the crowded city streets of London to find out if it really does do 148mpg. Turn to p90 to discover whether these next-gen eco vehicles live up to the marketing hype.





...spoke to zoologist, economist and author Matt Ridley about his new book, which argues that most 'human achievements' are in fact simply the result of ideas evolving over time.

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APPEARING IN THIS ISSUE...



Colin Stuart Astrophysicist, author and science presenter Colin admits that fellow

astronomer John Gribbin is one of his science heroes – so what will he make of Gribbin's new book? Find out on p106.



Zoe Cormier

This month, regular contributor Zoe looks at the beneficial effects

music can have on your mind and body (see p52). Well, who better to ask than the author of Sex, Drugs & Rock 'N' Roll?



Richard Dawkins

We visited the home of the evolutionary biologist and outspoken

atheist to discuss his many scientific achievements. What does he think has been his greatest work? Find out on p48.



David Spiegelhalter

Known for his work on risk, top statistician David says he's not very

good at maths. We don't believe him, but you can find out more about his life in science in our new feature on p114.



Turn to p16 and save yourself a whopping 40% of the cover price



SUBSCRIBER

On p16, **Dr Ian Whittaker** outlines the questions that are currently keeping solar scientists awake at night

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With evidence suggesting we're on the brink of a sixth mass extinction, what can we do to prevent it?

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The eminent evolutionary biologist and outspoken atheist on evolution, controversy and alien life

TUNE IN TO TREATMENT FM

PHOTOS: ANDY POTTS, DANNY ALLISON, GETTY, SCIENCE PHOTO LIBRARY, ROBERT HOLLINGWORTH, NEWSPRESS, BARTEK WACLAW & MARTIN NOWAK, ROBERT MATTHEWS, FRANK GREEAWAY

The surprising medical applications of music: from speech therapy to helping premature babies grow

THE MAN-MADE UNIVERSE

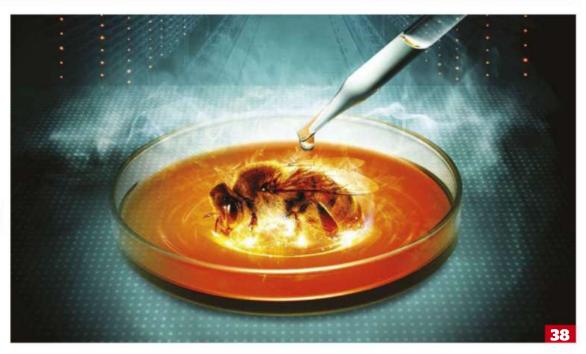
Scientists have managed to create an entire universe – inside a supercomputer

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Your face reveals more about you than you might think... here are 10 examples

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The story of how we came to understand hormones and their functions











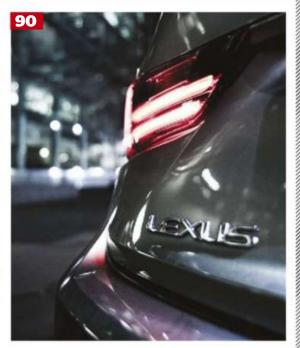
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MegaPixel

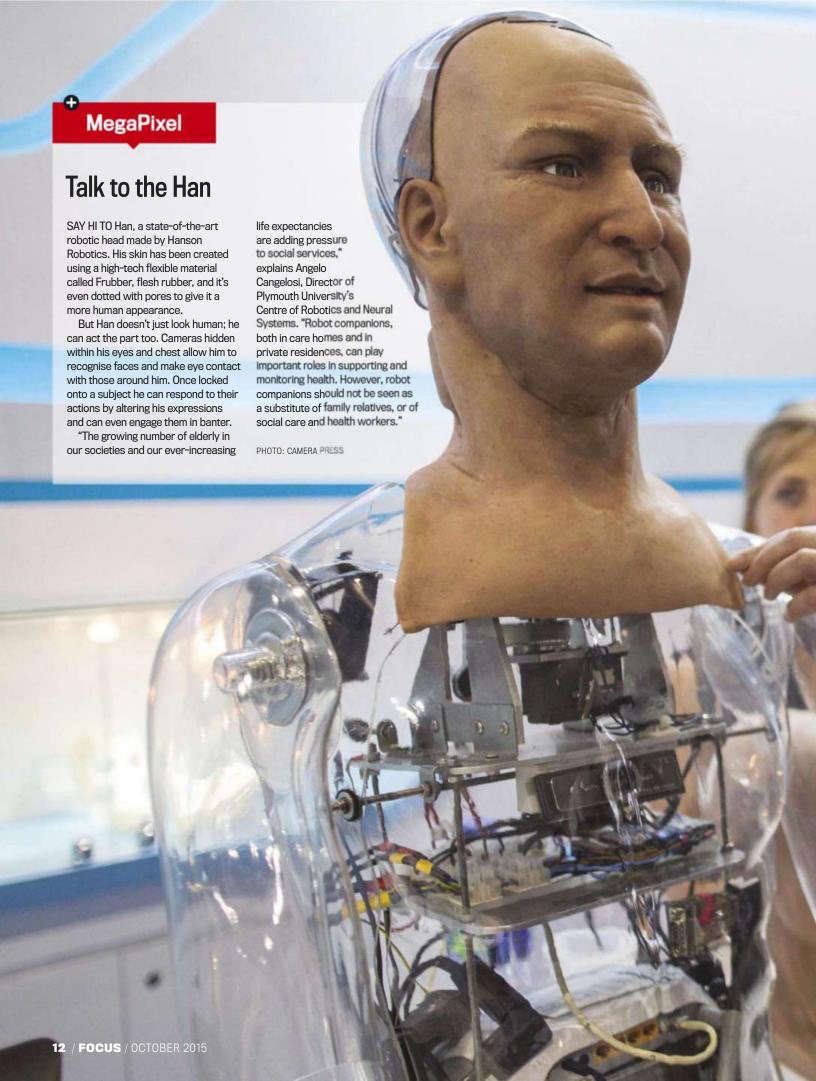
Ray of sunshine

THIS CUTE LITTLE fellow is a baby undulate ray, an endangered fish found in the Mediterranean and east Atlantic, including waters around the UK. The starry 'eyes' are actually the animal's nostrils, which it uses only for smell; it breathes using gills (the five pairs of gill slits are visible in this image beneath the mouth). In contrast to its white underside, its back is covered in a brown and yellow pattern that blends in perfectly with the sandy seabed. Although just several centimetres in length now, once fully grown this ray could measure up to 1m and live for as long as 23 years.

"Baby undulate rays start out life enclosed in a tough leathery eggcase. This small capsule protects the developing embryo, while a yolk sac provides all the required nutrients for it to grow," says Cat Gordon from the Shark Trust. "Tiny slits along the horns of the eggcase allow oxygenated seawater to enter the capsule and the ray will beat its tail like a pump to circulate it. Once hatched, the young are fully formed, miniature versions of the adults, ready to fend for themselves."

PHOTO: CAMERA PRESS











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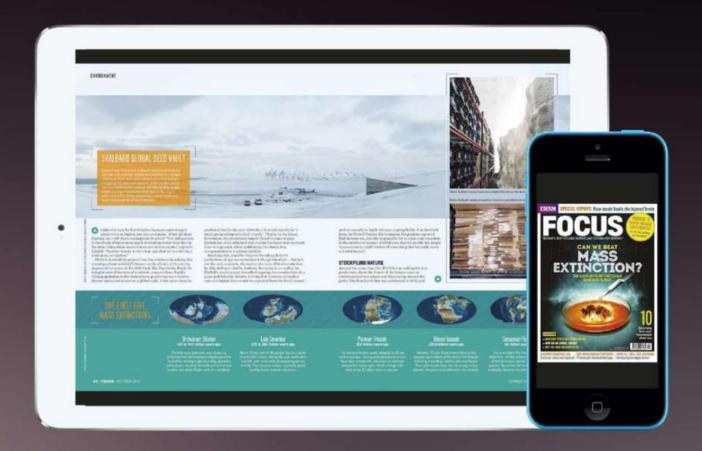
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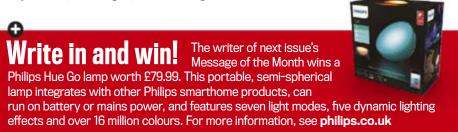


Wasps: the shocking truth

ONE MAJOR OMISSION in your wasps article (August, p56) – they attack honey bees. Every autumn, beekeepers have to restrict hive entrances in an attempt to prevent wasps robbing the bees' stores. If those attacks become too numerous, bees will leave their hive *en masse* and will often not survive the winter. I have lost several colonies because of wasp attacks; as a result I will kill any wasp, especially queens. I hardly call wasps 'beneficial' when they do this, especially considering the current plight of our honey bee populations.

The problem will become even more serious if – more likely when – the Asian predatory wasp arrives in this country, as this species will attack honey bees on sight.

Hally Hardie, beekeeper, Peterborough



Moon blindness

In reference to the question of why the Moon appears to change size: a long time ago I learned that the Moon does not alter in size and that if you hold two matches side-by-side at arm's length, and focus with one eye on the Moon, the matches will cover it.

Try it for yourself!

Douglas Regan



Dog's best friend

In reference to your 'Q&A' question on how humans tamed wolves (August, p76), I think you will find that, in an effort to limit the dangers of taking down large and dangerous animals, around 11,000 years ago wolves started to domesticate early humans to do the killing for them, after the wolves had done the tracking and cornering. Probably.

Pat MacDonell

Antenna man

Two apparently unrelated articles in your September issue of *Focus* were relevant to antenna design, which involves mathematics and computer optimisation.

First off, there was the piece by Robert Matthews (p21) on mathematics in schools. He was right: maths education concentrates on the wrong things. That said, you still have to do the boring stuff. It's important that the basic rules become

embedded in your mind early on, so that it is then free to do real thinking.

Which leads me to my second point. Helen Czerski's insight into how mist-proof mirrors work (p23) reminded me of a problem I've had when I worked on a microwave antenna. We had a feedhorn [the part of an antenna upon which transmissions are focused] that was sealed with a flat, plastic cap. In rain, the performance was degraded by the build-up of water droplets. We believed that applying a water repellent coating would cure it. Wrong, it was much worse!

As Helen says, the coating actually formed the water into a uniform sheet. Water has a high refractive index which acted as a lens, defocusing the horn. The solution was to curve the cap to throw the water off. We went further, making the cap itself into a lens and actually improving performance.

That work was done by trial and error. No doubt today a better solution could be obtained quicker using computer optimisation.

Geoff Dunwell, Maidenhead

Feeling fly

I was very interested to see the horsefly listed as the fastest flying insect in the March issue (p78). We spend time in France and have these insects fly into our conservatory at very high speeds. They hit the window with a great thump. Why are they not knocked out? What part of their body takes the impact?

They seem to just stop and then take off again with no harm done. I wonder if, with current camera technology, this impact has been filmed?

Nigel Watson

It's because they're so small and light and therefore don't carry much mass. This means that the force caused by the rapid deceleration is smaller than if you or I did the same. They're also very aerodynamic, which means that they can adjust their bodies just before impact.

- Alice Lipscombe-Southwell

Image conscious

I enjoyed your article 'Nature's hidden beauty' (September, p56) about Robert Hooke's work, but you missed out by not mentioning an important new photographic technique that really does show the hidden beauty of nature.

Electron micrographs, though minutely detailed, suffer from two failings: they cannot depict living subjects and they are invariably monochrome – except those that are artificially coloured afterwards.

The technique I am referring to here is computer stacking of sequential photos. This technique can be used on living subjects (though they have to be stationary) in natural poses and shows the subject in its true colours. I would like to draw your attention to the work of John Hallmén (johnhallmen.se). His images are both incredibly detailed and staggeringly beautiful.

Kim Taylor, Guildford



FOCUS SCIENCE AND TECHNOLOGY

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David Shukman goes to see a potentially life-saving new technology in action



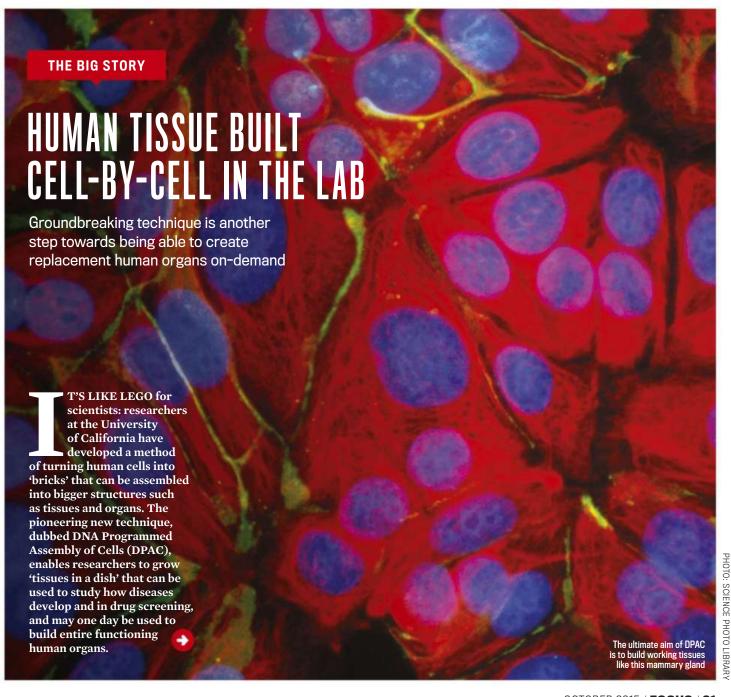
BATTLING CANCER

How computer models are shedding new light on tumours



JUNIOR JUPITER

A newly discovered exoplanet could reveal how gas giants are formed



The human body contains hundreds of different types of cell, with each type playing a unique role in keeping the body's various biological processes running smoothly. The way the cells organise within organs helps them coordinate their functions.

"Cells aren't lonely little automatons. They communicate through networks to make group decisions," explained researcher Zev Gartner, an associate professor at the University of California, San Francisco (UCSF). "We can take any cell type we want and program just where it goes. We can precisely control who's talking to whom and who's touching whom at the earliest stages. The cells then follow these initially programmed spatial cues to interact, move around, and develop into tissues over time."

Studying how the cells of complex tissues make decisions as groups is incredibly difficult in living organisms, thanks partly to their innate complexity and partly to the associated ethical issues. However, "this technique lets us produce simple components of tissue in a dish that we can easily study and manipulate," said fellow team member and

UCSF graduate student Michael Todhunter. "It lets us ask questions about complex human tissues without actually needing to do experiments on humans."

To create the organoids, the team fix tiny snippets of DNA onto the cells' outer membranes. These act as a kind of molecular Velcro that allows one cell to stick to another, provided it has complementary DNA. If the DNA sequences don't match, the cells don't stick. These cells can then be built up in layers to form complete organoids.

So far the team has created tissue that mimics veins, arteries and mammary glands. Next, they plan to use the technique to investigate the breakdown of tissue structure that is associated with tumours which spread and threaten the life of the patient. Ultimately, they hope to upscale their technique to build neural circuits and functional human organs such as lungs and kidneys.

"Building functional models of complex cellular networks such as those in the brain is one of the highest challenges you could aspire to," Todhunter said. "DPAC now makes that lofty goal seem much more achievable."

GOOD MONTH/ BAD MONTH

It's been good for:

SPICE LOVERS

Make mine a vindaloo: researchers at the University of Adelaide have discovered that eating spicy food may help to keep you trim. When the stomach stretches after eating, gastric nerves trigger to tell the brain it is full. The process is regulated by the TRPV1 protein, a receptor that's also activated when we eat chilli peppers.

CRYBABIES

Feel like having a good blub? Well, it's better to let it out. Researchers in the Netherlands found that volunteers who cried while watching a weepy movie were in a better spirits that their more stoic counterparts 90 minutes after it finished - despite their mood initially dipping.

It's been bad for:

THE SQUEAKY VOICED

If you fancy becoming a politician you might want to work on deepening your voice, a team at the University of Miami has found. When played two voice clips of a politician asking for votes, one higher pitched and one lower, 75 per cent of the participants chose the latter. The effect may be due to a deeper voice being associated with a high level of testosterone, strength and power. Brian Blessed for PM!

SHORT SLEEPERS

Late nights and early starts are the perfect recipe for catching colds, according to researchers at the University of California. They found that test subjects getting less than six hours sleep a night were 4.2 times more likely to catch the sniffles than those sleeping for seven or more.



TIMELINE

The guest to build human organs in the lab

Anthony Atala and his team at North Carolina's

Wake Forest University successfully transplant lab-grown bladders into seven human patients using tissue grafts.

2013 I

A team at Yokohama University in Japan grows tiny human livers using stem cells. Lab-grown organs may one day reduce our reliance on organ donations.

2014

Scientists at King's College London grow an epidermis, the outer laver of skin, using human stem cells. It could be used in place of animals in drug and cosmetic testing.

Researchers at the University of California make a tiny, beating heart by creating stem cells from human skin cells and manipulating them as they develop.



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22 / FOCUS / OCTOBER 2015

Can science help protect planes from terrorists?

DAVID SHUKMAN

The science that matters



T A GRAVEYARD for old jets, a curious experiment was taking place. At Cotswold Airport near Cirencester, engineers were inside a disused Airbus getting ready for an unusual task: to detonate a bomb.

After years of lab tests, this was the moment of truth for a system, called Fly-Bag2, for resisting explosions onboard an aircraft. Fly-Bag2 consists of four layers of fabric, including bulletproof Kevlar, stitched into the shape of a large box, into which the passengers' luggage is placed.

Cameras were ready as the detonation switch was flicked. As we stood a safe distance away, there was the sound of a muffled boom. The plane itself did not seem to move at all. When the air cleared, we clambered inside the aircraft's hold. The smell of explosive hung in the air. But while some luggage inside the bag was charred, the bag itself – remarkably – was unscathed.

The shockwave, pressure and heat had been overcome by a clever mix of strength and flexibility. The design is the result of materials research and sophisticated modelling at the University of Sheffield and a dozen other European institutions and companies.



The motivation for the project is the risk of another Lockerbie, when a bomb in the luggage of Pan Am flight 103 killed 270 people in the air and on the ground in 1988. Since then, airport security has improved immeasurably and on some routes airlines pay for extra searches, or even bring in their own teams. But the logic of the team behind Fly-Bag2 is that no airport screening can be 100 per cent foolproof, so surely it's better to have a last line of defence.

been out of their sight since

It's up to the airlines to decide whether to buy the system. It would inevitably add to their costs, and may make tickets more expensive. But watching high-speed video shot at the instant of the explosion is not only impressive but also reassuring: the walls of the bag bulge and billow but, crucially, do not give way.

DAVID SHUKMAN is the BBC's Science Editor. @davidshukmanbbc



Fly-Bag2 could prevent a Lockerbie-style disaster

WHO'S IN THE NEWS?

Brenda Laster



Who is she?

A former director of the radiology lab at Israel's Ben-Gurion University of the Negev.

What has she been up to?

She has been ingesting small doses of hydrogen peroxide (H_2O_2) , a powerful chemical that's used to make explosives and hair bleach, on a daily basis for the last six years.

Why on Earth is she doing that?

Studies on nuclear disasters such as Chernobyl or Fukushima have found that the bodies of those hit by high doses of radiation produce fatal quantities of hydrogen peroxide. Laster believes she can teach her body to adapt to this.

So she's making herself radiation-proof?

That's the general idea. Lester hopes her daily dose of bleach will let her build up an immunity to the deadly H_2O_2 , just as vaccinations grant immunity against viruses.

What has she found?

She hasn't published any results yet, so watch this space. In the meantime, seriously: don't try this at home.

BIOLOGY

Cutting-edge imaging reveals inner workings of cells

HAVE YOU EVER wondered what's going on inside a cell? Well, now you can see for yourself. Researchers at the Howard Hughes Medical Institute have shot stunning 'movies' that capture biological processes as they occur within living cells.

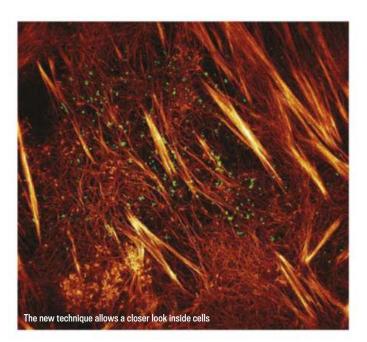
To produce the videos, the team, led by Nobel laureate Eric Betzig, made refinements to an existing technique called structured illumination microscopy (SIM). In regular SIM, the sample being imaged is illuminated by several different patterns of light. The reflections from the patterns are captured from a number of different angles and then combined to form a 3D image by computer

software. This enables the technique to produce images with twice the spatial resolution of traditional light microscopy.

However, prolonged light exposure can damage cells. To overcome this, the team periodically illuminated small sections of the sample at different times rather than the whole thing all of the time.

"These methods set a new standard for how far you can push the speed and noninvasiveness of super-resolution imaging," says Betzig. "This will bring super-resolution to livecell imaging for real."

They used the technique to show the action of proteins in muscles during contractions, and in a functioning kidney.



EVOLUTION

Giant sea scorpion fossil discovered

YOU WOULDN'T WANT to bump into this guy when you were out for a leisurely swim! Palaeontologists at Yale University have discovered fossils belonging to a giant predatory sea scorpion.

Dubbed *Pentecopterus* decorahensis, thanks to its resemblance in shape to the ancient Greek warship known as a penteconter, the animal could grow to almost two metres in length and had a heavily armoured head and large, grasping limbs for trapping prey.

The creature lived around 467 million years ago, making it the oldest eurypterid – a group of aquatic arthropods that were the ancestors of modern spiders, lobsters and ticks – discovered to date. Researchers say that it is likely to have lived in shallow, brackish water with a low salt content that would have been inhospitable to more typical marine animals.

"This discovery shows that eurypterids evolved some 10 million years earlier than we thought, and the relationship of the new animal to other eurypterids shows that they must have been very diverse during this early time of their evolution, even though they are very rare in the fossil record," said James Lamsdell, a post-doctoral geologist who was lead author of the study, which was published in the journal *BMC Evolutionary Biology*.

The fossils were unearthed in a flooded meteorite crater near to the Upper Iowa River in northeastern Iowa, USA. Both adult and juvenile *Pentecopterus decorahensis* specimens were found, giving the researchers a wealth of information about the animal's physiology and development. The lack of oxygen in the crater has also meant that the fossils are incredibly well preserved.



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1 MINUTE EXPERT

The lunar atmosphere



The Moon has an atmosphere?

Yep. NASA's LADEE craft has detected abundant levels of neon in the lunar atmosphere, which means we now know that it is mostly made up of neon, helium and argon.



Where does it come from?

Solar wind shoots into space from the Sun, and this gassy breeze containing hydrogen, helium and small volumes of other gases hits the surface of the Moon. Only helium, argon and neon are volatile enough to bounce back and enter the atmosphere, while the other gases stay on the surface.



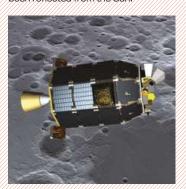
Can it get all that from solar wind?

The atmospheric gases are mostly provided by solar wind, but the Moon itself also has its own supply of gases. Argon-40 is released from the radioactive decay of potassium-40 and helium from the decay of thorium and uranium, elements that are found in lunar rocks.

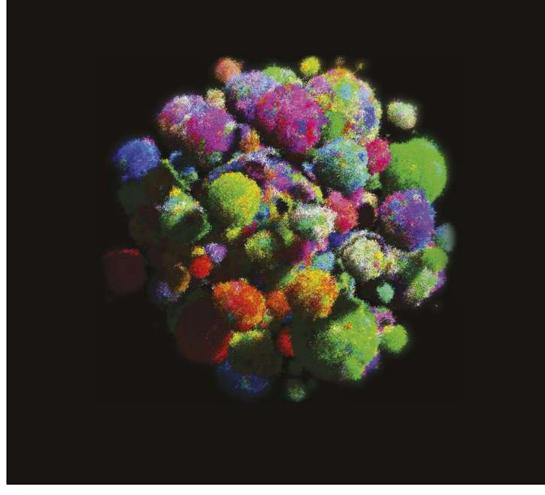


So is that why the Moon glows?

No, although neon is used to make bright nightclub signs here on Earth, the Moon's atmosphere is so thin that there is not enough neon to produce a glow. In fact, the Moon's atmosphere is 100 trillion times less dense than ours. The light that we see when we look up at the Moon has been reflected from the Sun.



NASA's LADEE spacecraft orbited the Moon from October 2013 until April 2014



MEDICINE

Cancer modelled in 3D for first time

IT MAY LOOK like a bunch of colourful pom-poms to the untrained eye, but this 3D computer model of a tumour may help researchers to develop more effective treatments for cancer.

The model was developed by an international team of scientists working at Harvard, Edinburgh and Johns Hopkins universities, and is the first that accurately portrays a tumour's 3D structure as well as its genetic evolution, with each different colour in the model representing a different mutation.

Cancer develops when the genes in a cell mutate and begin multiplying uncontrollably. If a mutated cell multiplies enough times, it can create a large clump of abnormal cells – a tumour. All cells accumulate mutations as they divide. Most are known as 'passenger' mutations and have little effect. In cancer cells, however, around 5 per cent of mutations allow cells to divide faster or live longer. These are known as 'driver' mutations. The model visualises how tumours grow over time and provides a key insight into the cells' ability

THEY DID WHAT?!

Biologists engineer 'brainy mice'

What did they do?

A University of Leeds team, led by Dr Steve Clapcote, altered a gene in mice that inhibited the activity of an enzyme called phosphodiesterase-4B (PDE4B), which is present in many organs, including the brain. They studied the effect this had on the mice's memories and problemsolving skills.

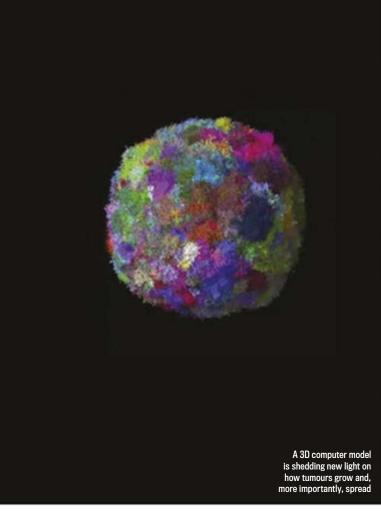
What did they find?

Compared to normal mice, the PDE4B-inhibited mice

learned faster, remembered things for longer and performed better at problemsolving. They also appeared to be less affected by scary experiences than unaltered mice, and spent less time cowering in corners.

Why did the scientists do that?

As PDE4B is also present in



to migrate away from the tumour and ultimately move to other places in the body in a process known as metastasis.

"Cellular mobility makes cancers grow fast, and it makes cancers homogenous in the sense that cancer cells share a common set of mutations." said Harvard's Martin Nowak, who led the research. "I further believe that the ability to form metastases, which is what actually kills patients, is a consequence of selection for local migration."

Driver mutations also play a role in drug resistance. If

a small number of cells are resistant to a therapy, they can quickly replicate, causing a relapse of the cancer even if nearly all of the other cancerous cells are wiped out.

"Our approach does not provide a miraculous cure for cancer." said the University of Edinburgh's Bartek Waclaw, who was also involved in creating the new 3D model. "However, it suggests possible ways of improving cancer therapy. One of them could be targeting local cellular migration and not just growth, as standard therapies do."

human brains, the work may help to shed light on the molecular mechanisms of learning and memory. Further down the line, it could also form the basis for further research into treatments for age-related cognitive impairment and cognitive disorders, such as Alzheimer's disease and schizophrenia.



Pi to over 17,500 decimal place

PATENTLY OBVIOUS with James Lloyd

Inventions and discoveries that will change the world

Fruity tattoos

FOR THOSE WHO want a tattoo, but aren't quite ready to be permanently inked, how about one that lasts for two weeks? Unlike other temporary tats, Inkbox's designs last for more than just a few days. The secret lies in a fruitbased formula that stains the top layer of skin (the epidermis) but, unlike conventional tattoos, not the laver beneath (the dermis). Place the adhesive stencil on the skin. hold a wet cloth over it for 10 minutes, and wait 24 hours for the tattoo to appear. Hipster heaven! Patent pending

Diet dressing

IMAGINE IF LOSING weight was as easy as changing your clothes. That's the bold claim of Adam Paulin, creator of Thin Ice clothing. His insoles and vests are embedded with cooling chips essentially miniature heat pumps - that chill specific areas of the body. This localised cooling tricks the body into thinking it's in a cold environment, sending the metabolism into overdrive and burning off fat in the process. The makers say that the cold sensation disappears after a few seconds. Patent pending

Stairway to heaven

SPACE ELEVATORS ARE the stuff of sci-fi dreams, taking astronauts into space without the need for fuel-guzzling rockets. But there's one big problem: how do you build a structure tall enough, that's also strong enough to support its own weight?

Canadian space company Thoth Technology thinks it has a solution. It has patented a freestanding space tower that's composed of a series of pneumatic pressure cells. Each of these cells, made from a high-strength material such as Kevlar, is filled with pressurised gas, keeping the structure rigid as it gets buffeted by winds.

Reaching 20km (12 miles) into the sky, the elevator wouldn't take astronauts directly into orbit, Instead, it'd be used as a takeoff and landing pad for single-stage space planes, which Thoth claims will save more than 30 per cent of the fuel when compared to conventional rockets. The electrical elevator could also ferry scientists and tourists back and forth. Beats a trip to Magaluf, anyway...

Patent number: US 9,085,897



DISCOVERIES THAT 9 WILL SHAPE THE FUTURE WARRENT OF THE FUTURE TO SHAPE THE FUTURE TO

A step towards universal flu vaccine

IF YOU HATE going for an annual flu jab, there's hope on the horizon. Flu vaccines need to be updated every year to cope with new flu strains, caused by genetic mutations in the influenza virus. But now medics at America's National Institute of Allergy and Infectious Diseases have created a nanoparticle vaccine that targets the part of the virus that mutates the least. Antibodies produced by the vaccine didn't stop mice and ferrets catching flu, but they did prevent most of the animals dying from a normally lethal dose of H5N1 influenza.

Nanoparticles may make the annual flu jab a thing of the past

Disease detection

INFECTIOUS DISEASES CAUSE 22 per cent of deaths globally and detecting them quickly is essential to stop them spreading. Currently, outbreaks are monitored by compiling doctors' reports, but carrying out genetic analysis of toilet waste on aircraft could speed things up. By studying waste arriving from both North and South Asia and North America, scientists at the Technical University of Denmark found geographical differences, including more Salmonella enterica in samples from South Asia



More Salmonella enterica was found in the contents of aeroplane toilets on flights arriving from South Asia

The perfect pea

PEAS ARE TASTY but they contain protease inhibitors that prevent us from getting all their nutritious proteins. But now scientists at the John Innes Centre have identified wild peas that possess genetic mutations that reduce the effect of these inhibitors.



Mutant peas make getting more nutrition easy peasy

New drug helps alcoholics recover

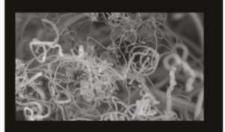
A DRUG FOR treating alcoholism without causing depression could be available within five years. Existing treatments target the dopamine release that alcohol triggers in the brain but can leave patients depressed. Now scientists at the University of Wisconsin, Milwaukee have made compounds that **reduced both the amount of alcohol drunk by test rats and their anxiety**.





Making money from CO₂

IT SEEMS THE perfect solution to climate change: suck carbon dioxide out of the atmosphere and do something useful with it. Scientists at George Washington University have done this by producing carbon nanofibres (below), worth hundreds of times more than the cost of making them, from atmospheric CO₂. They can be used in tennis rackets, turbine blades and even planes.

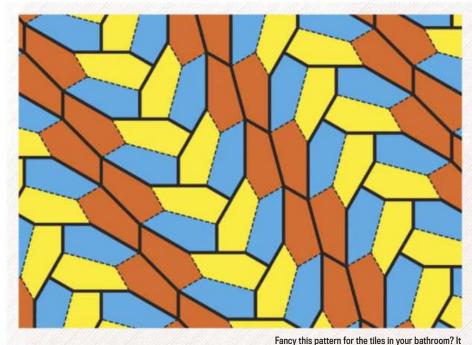




DNA 'hard disks'

IF DNA WERE used in place of hard disks, you could store a staggering 300,000TB in just one gram. **The** advantage of DNA storage, as demonstrated by a team led by ETH Zurich researcher Robert Grass, is that it can last up to 2,000 years. It'll be a long time, though, before the technology is cheap enough and ready for the mainstream.





Practical

pentagon

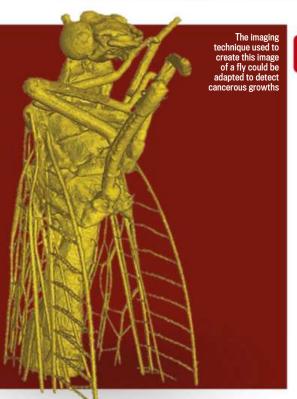
MUCH AS YOU might like to, you can't tile your bathroom using any shapes with more than six sides - it's mathematically impossible. But finding useable shapes with five sides isn't easy either. A shape just discovered at the University of Washington

may not be aesthetically pleasing (at least not in these colours) but it is mathematically possible

is only the 15th pentagon capable of doing it - and is the first to be found in 30 years. As well as tiling, it could have practical uses in architecture and drug design, in which new compounds are created from chemical building blocks.

Laser X-rays save money and lives

A NEW KIND of X-ray technique may one day be able to reveal small cancerous tumours before they have the chance to spread through the body. Cancerous tissue is less dense than healthy tissue – a difference the new method can detect. Researchers at the Max Planck Institute of Quantum Optics tested it by making a highly detailed 3D image of a small fly. Unlike similar images produced using huge particle accelerators, the new technique is cheaper as it uses X-rays generated by a laser.



White lasers

RED AND GREEN lasers are nothing new. Now, Arizona State University scientists have combined red, green and blue beams to create the world's first white laser. In time, white lasers are likely to replace LEDs in lighting and displays because they're more energy-efficient and **brighter.** White laser light bulbs could also transmit information, giving your home a wireless network that's 10 times faster than existing Wi-Fi.

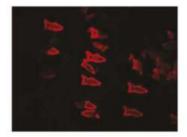
Combining red, blue and lasers creates an energy-efficient white beam

Here to help: tiny 3D-printed robot fish

THE NEXT TIME you get sick, your illness may be treated by a school of tiny 'microfish'. A team at the University of California has created 3D-printed fish-shaped microrobots that are capable of swimming through liquid and carrying payloads. They could be used for removing toxins or delivering drugs to specific areas of the body.

The bots measure just 120 microns by 30 microns and were printed using a technique called 'microscale continuous optical printing', in which UV light is shined onto a photosensitive material, causing it to solidify. They are built up one layer at a time. This process allows various nanoparticles to be inserted into specific areas to give them specific properties. Platinum nanoparticles in their tails propelled them through a solution of hydrogen peroxide in which they were tested, and iron oxide in their heads allowed them to be steered using magnets. The whole process takes seconds and doesn't rely on the use of harmful chemicals.

"We have developed an entirely new method to engineer nature-inspired microscopic swimmers that have complex geometric structures and are smaller than the width

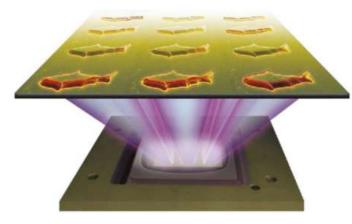


The PDA-laden robotic fish glowed red as they removed toxins from a solution

of a human hair. With this method, we can easily integrate different functions inside these tiny robotic swimmers," said researcher Wei Zhu.

To test their concept, the team printed fish embedded with toxin-eating polydiacetylene (PDA) nanoparticles and plunged them into a toxic solution. As PDA fluoresces red when it binds with toxins, the team was able to monitor the bots' detoxification ability by the intensity of the red glow.

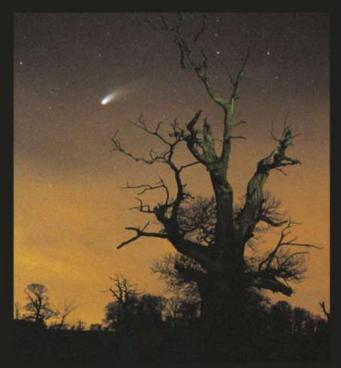
"This method has made it easier for us to test different designs for these microrobots and to try out different nanoparticles to insert new functional elements into these tiny structures. It's my personal hope to further this research to eventually develop surgical microrobots that operate more safely and with more precision," said researcher Jinxing Li.



The 'fish' are created using a technique called microscale continuous optical printing and can be customised for a variety of different medical applications

ASTROBIOLOGY

Did life on Earth come from comets?



Comets are an impressive sight, but we might owe our very existence to them

THE MERE MENTION of comets crashing into the Earth is likely to bring to mind images of mass extinction and the end of days. But researchers at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) have found further evidence that comet impact may have been vital for the creation of life as we know it.

The team ran a series of experiments aimed at mimicking the kind of comet impacts that are likely to have occurred on Earth at the time when life first appeared, around four billion years ago. They made a mixture of amino acids (the so-called 'building blocks' of life), ice and forsterite, a mineral often found in meteorites. They then cooled it to 77°K and bombarded it with a propellant gun, to simulate the force of a comet impact.

Analysis of the resulting mixture showed that a number of the amino acids had joined together into short chains called peptides. "This finding indicates that comet impacts almost certainly played an important role in delivering the seeds of life to the early Earth," said Haruna Sugahara, who was lead author of the study.

"The production of short peptides is a key step in the chemical evolution of complex molecules. Once the process is kick-started, then much less energy is needed to make longer chain peptides in a terrestrial, aquatic environment." The work also suggests that the same process could have occurred on other planets and other extraterrestrial bodies.

"Within our own Solar System, the icy satellites of Jupiter and Saturn such as Europa and Enceladus are likely to have undergone a similar comet bombardment. The NASA stardust mission has shown the presence of the amino acid glycine in comets," Sugahara added.



ROBERT MATTHEWS

PUTTING RESEARCH TO THE TEST

Students could put an end to false scientific claims once and for all

UESTIONING AUTHORITY IS all part of growing up – and one of the foundations of science. It's crystallised in the motto of the Royal Society: *Nullius in Verba*. Roughly, "Take nobody's word for it."

By giving us the tools like the experimental method to question what we're told, science has freed us from all kinds of twaddle peddled by authority figures. Without it, we'd still be in thrall to Aristotle and friends, who thought diseases are caused by bad air and the Sun orbits the Earth.

Yet there's a growing feeling in the research community that science could be doing a better job of questioning its own authority. The suspicion is that the pressure on researchers to produce something – anything – is leading to a lot of junk being published and going unchallenged.

When new research is submitted to a journal, its claims undergo peer review. But that's usually just a check of the claims' logic and whether the researchers have made their case. Attempts to replicate them independently only come later. Or more likely, never: of the hundreds of thousands of scientific papers published every year, around 30 per cent are never cited again, let alone have their claims replicated.

The reasons for this are understandable. While scientists recognise the need for replication, most are too busy to spend time checking others' work. As a result, it's usually only the most dramatic claims that get replicated. But worryingly, they often fail the test. Remember those stories about

faster-than-light neutrinos from researchers at CERN a few years back? Or that amazingly simple way of making stem cells unveiled last year by Japanese scientists? These headline-grabbing claims were quickly debunked once others tried to replicate them. All of which makes you

"While scientists recognise the need for replication, most are too busy to spend time checking others' work"

wonder about the trustworthiness of the other, less eye-catching claims out there. Some of them have been put to the test and the results aren't encouraging. An ongoing attempt to replicate the results of 100 studies in psychology is said to have vindicated fewer than 40.

Small wonder, then, that there is mounting concern about the reliability of scientific research and great deal of soul-searching about how to tackle it. If hard-pressed, professional scientists can't - or won't - take on replications, who can?



There is one intriguing solution currently doing the rounds: why not use replications as science projects for students? Some researchers argue that only graduate students can be trusted to do a good job but others are already using replications as an introduction to what real research is like.

I'd go further. Given proper supervision, I don't see why some replications couldn't be turned into school or even public projects. Is it true, for example, that people walk more slowly after being exposed to words associated with old age – as one study recently claimed? Or that we make better choices when presented with around half a dozen options rather than 20?

Trying to replicate such claims would convey more about doing science than any number of boring lectures. And it could make a real contribution by casting light on the reliability of the original research. This is surely a golden opportunity for official bodies such as the Royal Society to show

they're serious about getting people engaged with real science. After all, they're keen to encourage the public to use science to question authority figures – aren't they?

ROBERT MATTHEWS is Visiting Professor in Science at Aston University, Birmingham

ASTRONOMY

Exoplanet could shed light on birth of the Solar System

SAY HELLO TO 51 Eridani b, the 'younger cousin' of Jupiter that may help scientists figure out how our Solar System was formed. The exoplanet was spotted orbiting a young star 100 light-years away by the Gemini Planet Imager (GPI), a planet-hunting instrument installed on Chile's Gemini South Telescope. It's roughly twice the mass of Jupiter, with a surface temperature of around 430°C and an atmosphere rich in methane. The planetary system it inhabits is just 20 million years old, much younger than our own 4.5-billion-yearold Solar System, and could provide clues as to what Jupiter looked like in its infancy.

"In the atmospheres of the cold giant planets of our Solar System, carbon is found as methane, unlike most exoplanets, where carbon has mostly been found in the form of carbon monoxide," said Mark Marley, of NASA Ames Research Center. "Since the atmosphere of 51 Eridani b is also methanerich, it signifies that this planet is well on its way to becoming a cousin of our own Jupiter."

Astronomers believe that the gas giants in our Solar System, such as Jupiter and Saturn, formed by first gathering up a large core of heavy elements over the course of millions of years, which then pulled in vast quantities of surrounding hydrogen and other gases to form an atmosphere. However, the Jupiter-like exoplanets so far discovered don't fit with the predictions of current models. Further study of young planets such as 51 Eridani b may help to explain why this is.





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HELEN CZERSKI BAFFLEMENT AT BATHTIME

Why aren't there any red bubbles?

SOAP BUBBLE IS almost like a magic pill for making people smile. They're easy to create, beautifully spherical, innocent and airy with a hint of unpredictability. And they're colourful. But once you've watched them for a while, you notice something strange. The shifting swirls gliding over the surface are pink and green, sometimes with streaks of yellow and occasionally blue. But where are the other colours? What about red and purple, brown and orange? What makes a bubble so selective?

Possibly the only thing about bubbles that has consistently been disappointing to generations – other than the fact you can't catch them – is that you can't change the colour of a bubble by adding food dye. There's just not enough of it: a typical soap bubble is so thin that it only has a few milligrams of water in it. The minuscule amount of dye in there can't absorb enough of the flood of light passing through to make any difference.

But it's this skinny film that gives a bubble its colour. That curved outer surface is reflective, and so is the inner surface. Light behaves like a wave in situations like this. So just like ripples on a pond, those two reflected waves add together, either to reinforce each other or cancel each other out. The light reflected off the interior has travelled further and it may or may not line up with the light reflected off the exterior on its way out of the bubble. If the wave reinforces itself, lots of the colour corresponding to that wavelength will escape to be seen.

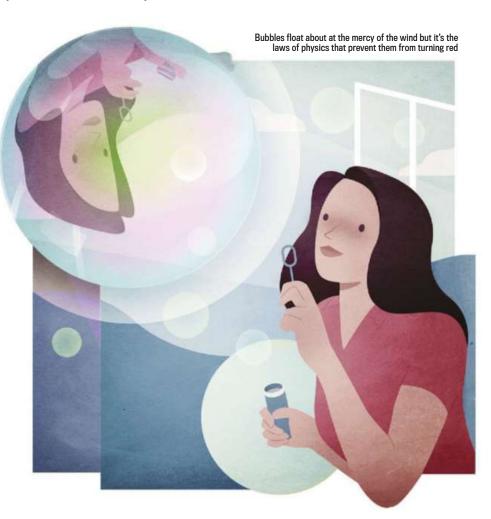
So far, so good. Lots of colours could be produced this way. But where's my red bubble?

The ripples of light waves spreading out from the bubble have all the colours of the rainbow. But we don't see those colours individually, because often the same thickness

"Pink looks like a colour but it isn't in the rainbow - our brains have made it up as a way of dealing with red plus violet"

of soap film will give us a few different colours together. It just so happens that the thickness that gives us lots of red also gives us lots of violet. But we only see a single colour: pink.

The violet wave will have rippled four times before coming back out while the red one will have rippled three times, but they're both back where they started as they leave the bubble. Pink looks like a single colour but it isn't in the rainbow – our brains have made it up as a way of dealing with red plus violet.



If the soap film forming the bubble's surface thins a bit more, the red and the violet waves cancel each other out, which leaves you with lots of green. Green is a single wavelength, a real colour from the rainbow. And as the film thins further, there's a point where there's lots of red and green together (they've rippled approximately twice each) but no blue, so you end up seeing yellow.

We only see colours when the soap film is very thin – a thickness of just one or two wavelengths of light. So there are only a limited number of combinations of colours that we can see. Red by itself just happens not to be one of them. So no red bubbles for me.

It can be unsatisfying when the answer to a question is 'that's just the way it is', but I don't mind it in this case because it's universal. Every single soap bubble obeys the same rules; it doesn't matter how you

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose most recent series was Super Senses make it, where you make it or what you make it with. Sometimes it's reassuring to see the fundamental rules of the Universe at work. Pink and green bubbles are just the way the Universe rolls.

ASTRONOMY

Astronomers show that galaxies can change shape

THE FIRST EVIDENCE that galaxies can change shape has been found by an international team of astronomers led by Prof Steve Eales from Cardiff University's School of Physics and Astronomy.

"Many people have claimed before that this metamorphosis has occurred, but by combining Herschel and Hubble, we have for the first time been able to accurately measure the extent of this transformation," said Eales. His team published their findings in the journal Monthly Notices Of The Royal Astronomical Society in August.

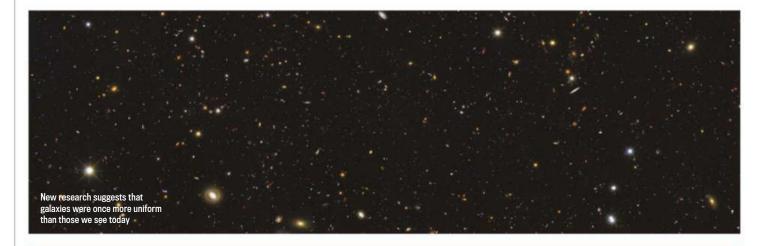
The team were able to do this after making observations of 10,000 galaxies and classifying them into two types: rotating, flat discs (such as the Milky Way) or large, spherical galaxies. Then, using the Hubble and Herschel telescopes to peer

at galaxies much further away
– and thus much further back
in time – the team were able to
compare today's galaxies with
those formed in the aftermath of
the Big Bang.

Eales's team found that 83 per cent of the stars formed immediately after the Big Bang were located in rotating disc galaxies. But today only 49 per cent of stars are found in such galaxies, with the rest found in

large, spherical ones, suggesting many galaxies have undergone major transformations during their lifetimes.

One possible cause for such a transformation could be two disc galaxies merging into one another after colliding. But it's also thought there may be cases where stars in a disc galaxy are drawn towards the centre and group together to form a spherical galaxy.



PSYCHOLOGY

Link between neuroticism and creativity explained

DO YOU LIE awake, fretting over the tiniest of problems? You may be a creative genius!

It's long been known that people who suffer from neurotic thoughts tend to perform better in creativity tests than their calmer counterparts, but now Dr Adam Perkins of King's College London has come up with an explanation as to why.

Previous MRI studies have shown that those who have spontaneous negative thoughts, a key marker of neuroticism, have increased activity in the medial prefrontal cortex, a brain region associated with threat perception. It's also been shown that the amygdala, the brain's emotional centre, acts a switch that controls when an individual goes into 'panic mode'. Perkins believes a combination of high activity in the medial prefrontal cortex and an over-sensitive 'panic switch' gives neurotics an increased tendency to imagine threats when none are present – as well as a highly active imagination that could make them more creative.

"We're still a long way off fully explaining neuroticism, but we hope our new theory will help people make sense of their own experiences, and show that although being highly neurotic is unpleasant, it also has creative benefits," Perkins said.



STEPHEN BAXTER ONE WORLD TO RULE THEM ALL

Could a single, unified government be inevitable?

EPTEMBER 2015 SEES the 50th anniversary of the first showing of Gerry Anderson's *Thunderbirds*, which was successfully revived by ITV this year. Like most of Anderson's 1960s shows, *Thunderbirds* was set against a background of a world government. "We now had the United Nations and I imagined, rightly or wrongly, that there would be a world government in the future," Anderson said.

This was a common assumption in science fiction at the time, and was inspired by the multinational institutions that emerged after WWII – the UN, the EU. Their purpose was to prevent another war, to provide mediation between countries armed with atomic weapons, and to manage challenges like poverty on a larger scale.

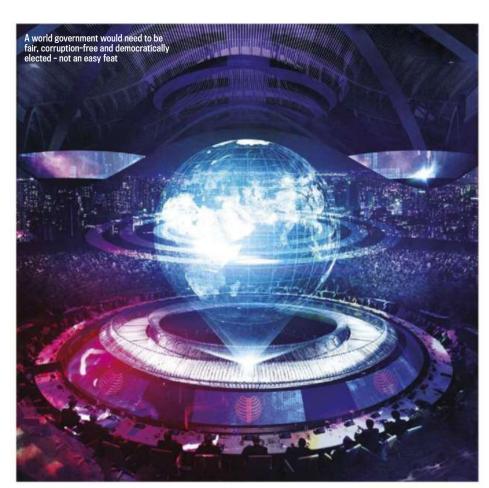
But the idea of a world government has a long history. The Spanish philosopher Francisco de Vitoria, who was born before Columbus sailed to the Americas, developed ideas of international law and a global state based on the experience of the growing Spanish empire. The idea was explored by such thinkers as Immanuel Kant and even Prince Albert, who dreamed of uniting the empires of Europe with bonds of royal marriage. as if one sprawling dynasty ruled all. HG Wells's A Modern Utopia (1905) was a modern world state with unified travel, communications and economic management. But it was not truly democratic, being governed by a self-selecting elite class called 'Samurai'. Ensuring democratic accountability in a world state is an enduring challenge.

Imagining world governments is difficult, but most of us lack historical perspective. At present, much of the world's political power is vested in the nation states, but this is a comparatively recent development. It was only as recently as 1918,

"As the nation state dissolves away, we may not have much choice but to accept a world government"

after WWI, that Europe's old empires - crude, undemocratic examples of unification - dissolved to yield the patchwork of nations we see today.

Technology may yet drive us towards unification. In his novel 2061 (1987), Arthur C Clarke foresaw how, by the middle of this century, "the human species...[would be] merging together, as the old linguistic and cultural divisions began to blur." Even today you can become an 'e-resident' of Estonia, enjoying some rights of citizenship no matter where you live physically.



In the modern world we are driven to cooperate on a large scale because we face threats that cross national boundaries, such as climate change. Some proposed solutions to such problems – such as the erection of shields in space to block sunlight – would have cross-border effects, and therefore would require an international consensus. Looking further ahead, space advocates argue strongly for unified governance as we move beyond the Earth. While space offers huge resources and room to grow, the initial investment costs may be too great for any single nation to bear, and a war waged by rival states armed with the energies required for interplanetary travel could wipe us out altogether.

On the one hand, such challenges may accelerate the trend towards strengthening international institutions like the EU and the UN. On the other hand, there may be a move towards devolving power down to the

STEPHEN BAXTER is a science fiction writer who has written over 40 books. His latest is *Ultima*, published by Orion regions to manage local issues. And as the nation state dissolves away, we may not have much choice but to accept a world government.

Maybe Gerry Anderson had it right after all.



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BEATING MASS EXTINCTION

All the signs in nature suggest another mass extinction is imminent – and this time humans, rather than a meteorite, are the root cause. But we're also working on ways to save the species facing peril, as **Duncan Geere** discovers....

LL AROUND THE world, mankind is hacking enormous branches off the tree of life. Since the last ice age – which ended about 10,000 years ago – the extinction rates of plant, mammal, bird, insect, amphibian and reptile species have skyrocketed, with one estimate putting the current rate of loss at up to 140,000 species per year. That's a problem – not just for the species that are dying out but for humans, too. We depend on our companions for food security, clean water, clothing and even the air we breathe (see p46).

In 2009, the Stockholm Resilience Centre listed biodiversity loss as one of nine 'planetary boundaries' that cannot be crossed without the world suffering irreversible environmental change (other boundaries include ozone depletion, climate change and ocean acidification). Without Earth's biodiversity, humans wouldn't be here at all. And even the most conservative estimates of species loss show cause for alarm.

PLANET IN PERIL

The latest calculations come from a group of biologists led by Stanford University's Paul Ehrlich and Gerardo Ceballos from the National Autonomous University of Mexico, who have published results showing that Earth is experiencing the beginnings of an extinction event at least as large as the one the killed the dinosaurs, and perhaps as big as the other four major extinctions in our planet's history (see below). "We're not there yet but we can easily get there in a century," Ehrlich says.

Their paper sets out a best-case scenario – one that only counts species as going extinct if we've seen them go extinct, and where the 'normal'



extinction rate for Earth before humans came along is about twice as high as previous estimates. What did their findings say, with these assumptions in place? "You still get tens to hundreds of times more rapid extinctions today than during the times when there weren't mass extinction events," explains Ehrlich. "In other words, a very clear sign that we're entering a sixth mass extinction."

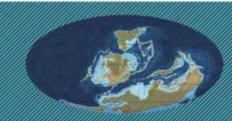
Ehrlich, it should be pointed out, has a history of making dire warnings about mankind's impact on the planet, with varying degrees of accuracy. In his 1968 book *The Population Bomb*, he brought several decades of academic concern about Earth's rising population to the mainstream, predicting mass famine, disease and social unrest on a global scale. A few years later, he

predicted that by the year 2000 the UK would merely be "a small group of impoverished islands". Thanks to the Green Revolution, his predictions largely failed to come to pass. Ehrlich has since admitted that society has been more resilient than he expected, while reaffirming his stance that overpopulation is a serious problem.

Knowing this, you'd be forgiven for taking Erlich's predictions of species extinction with a pinch of salt – but he's not the only academic alarmed at the rates of biodiversity loss. In 2011, biologists led by Anthony Barnosky (a co-author on Ehrlich's recent paper) described ongoing mass extinctions in a paper published in *Nature*, writing that "current extinction rates are higher than would be expected from the fossil record."

THE FIRST FIVE MASS EXTINCTIONS



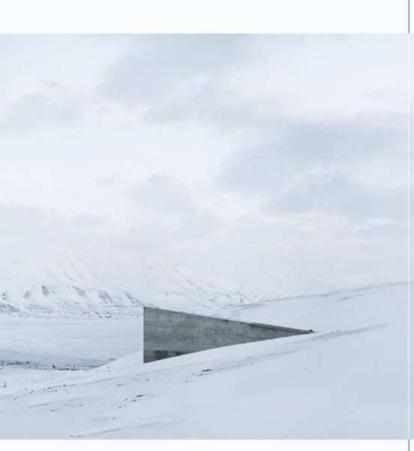


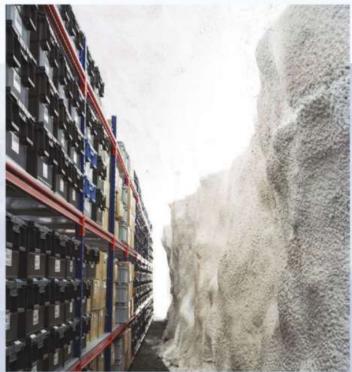
Ordovician-Silurian 447 to 443 million years ago

The first mass extinction was caused by protocontinent Gondwana moving towards the South Pole, leading to global cooling, glaciation and a drop in sea level. Most life at the time was marine, and about 85 per cent of it vanished.

Late Devonian 375 to 360 million years ago

About 70 per cent of all species died in a series of extinction pulses. Marine life was particularly hard hit, with coral reefs disappearing almost entirely. The cause is unclear – possibly global cooling due to oceanic volcanism.





Above: Svalbard houses frozen seed samples from all over the world

Below: Svalbard's seeds are carefully stored in a controlled environment

And as recently as April this year, a group led by Tim Newbold from the United Nations Environment Programme reported that humans are directly responsible for a 13 per cent reduction in the number of species. Ehrlich says that his results are simply "a conservative confirmation of something that basically every scientist knows".

STOCKPILING NATURE

Around the same time that Ehrlich was making his dire predictions about the future of the human race, an environmental movement was blossoming around the globe. The first Earth Day was celebrated in 1970, and







Permian-Triassic 252 million years ago

The worst extinction event, killing 90 to 96 per cent of species. The cause is debated but could have been a meteorite, volcanism or methane release that led to rapid climate change. Life took about 10 million years to recover.



Triassic-Jurassic 201.3 million years ago

Between 70 and 75 per cent of the Earth's species went extinct at the end of the Triassic, including many large reptiles and amphibians. The cause is unknown, but the empty niches allowed dinosaurs to proliferate in the Jurassic.

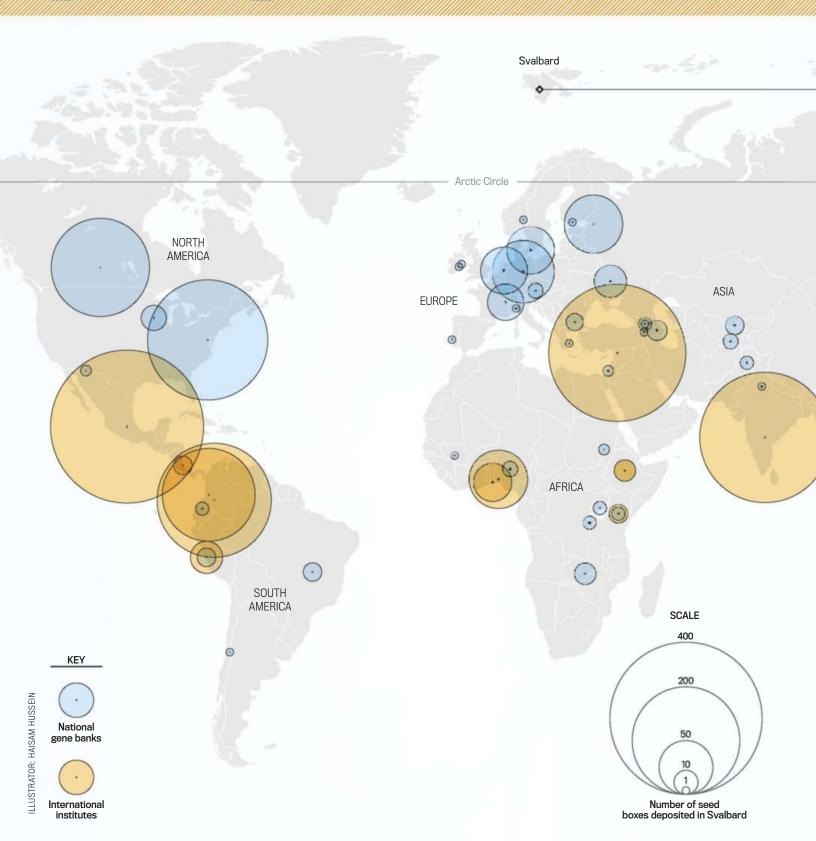


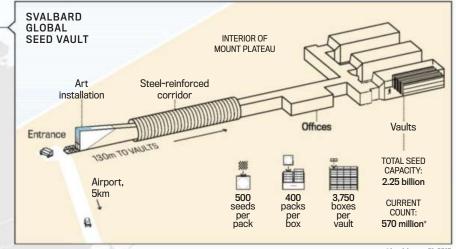
Cretaceous-Paleogene 66 million years ago

This is probably the most famous mass extinction – it's the asteroid impact that killed off the dinosaurs and about 75 per cent of species. Since then, birds and mammals have evolved to become the dominant land species.

THE GLOBAL SEED BANK NETWORK

Small gene banks and international institutes from around the world all deposit seeds into Svalbard





*As of August 31, 2015

LARGEST SEED STOCKS IN STORAGE IN SVALBARD (In millions)

Pearl millet

Rice

Goosegrass

Wheat

Sorghum

OCEANIA

Barley

Cicer (chickpea)

Source:

www.nordgen.org/sgsv/

0

Greenpeace was founded in 1971. All over the world, various scattered, underfunded conservation schemes began to join up into a wider network dedicated to preserving the world's animals and plants.

In 1992, 168 countries signed the United Nations' Convention on Biological Diversity, in recognition that conservation of biological diversity is "a common concern of humankind". That convention underpins many of the laws that protect biodiversity around the world today – it is seen as a vital document for conservation and sustainable development. One major project under its auspices, for example, is the Global Strategy for Plant Conservation, which includes 16 ambitious targets for understanding and conserving plant diversity.

Another example is a treaty that came into force in 2004 with the objective of guaranteeing food security through conservation and sustainable use of the world's plants. It called for the creation of a Global Crop Diversity Trust, which could ensure the availability of plant diversity essential for food and agriculture. This organisation, based in Germany and known more commonly as the Crop Trust, funds a global network of gene banks, where seeds and other genetic material can be preserved for decades, if not centuries.

"We work around the world with collections of crop diversity, to conserve them and make them available to farmers, breeders and scientists forever," explains Brian Lainoff from the Crop Trust. "It's important to have this diversity for the future so that scientists and breeders can grow crops that will have to be able to face higher temperatures, less water, new diseases and new pests. Without the diversity, the building blocks of agriculture don't exist."

FORT KNOX FOR NATURE

The Crop Trust works with national gene banks representing whole countries, as well as those focused on a particular crop, such as the International Rice Research Institute in the Philippines. But it also has one of its own – the Svalbard Global Seed Vault, dug into the side of a mountain on a frigid island just

11,300km (810 miles) from the North Pole, where the Sun doesn't rise for more than four months during winter. "We need a backup for the world's gene banks," says Roland von Bothmer from the Nordic Gene Resource Centre, which helps operate the facility. "That's what the Svalbard Seed Vault is."

There are seeds sitting on the shelves of Svalbard's vault from 5,103 species and 232 countries – including several, such as Yugoslavia, that no longer exist. Svalbard was chosen because it's geologically stable and because the frozen ground means that cooling the seeds to the necessary temperature for storage is easier. The remote location reduces the chances of sabotage and the entrance is 130m (425ft) above sea level, meaning that it'll be safe from rising oceans even if both of Earth's ice caps

"Svalbard is designed to last for centuries, if not millennia"

melt. Lainoff, who admits to being "not a very religious person", describes it as being like a cathedral. "It's deathly quiet," he says. "You feel very safe there."

The global gene banks split samples between three locations: their 'home' bank, a second bank in another country, and also in Svalbard where only the depositing organisation can access them. As such, withdrawals are rare. "We've been working for

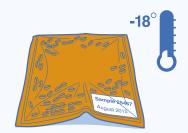
HOW TO HARVEST SEEDS



The first step is to gather some seeds from wild plants. Collecting expeditions prioritise locations with high biodiversity but threatened habitats. It's vital to record as much data as possible about where the seeds come from – not just the location but also the ecosystem.



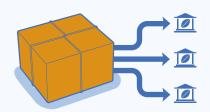
A Seeds stored in a seed bank must be periodically tested to establish whether they are still viable. For most seeds, testing is performed every 10 years. Svalbard just stores seeds – it does not test them, otherwise there could be accusations of contamination.



2 A temperature- and humidity-controlled room is used to reduce the moisture content of the seeds and then they're placed in sealed, airtight bags. Samples are then frozen to -18°C. This is the temperature that works best to preserve the majority of seeds for the longest possible time.



5 Fifty seeds of a batch are tested at once. They are wrapped in moistened filter paper or are rolled between paper sheets. After a few days, the number of germinated seeds is counted and a viability percentage is then calculated.

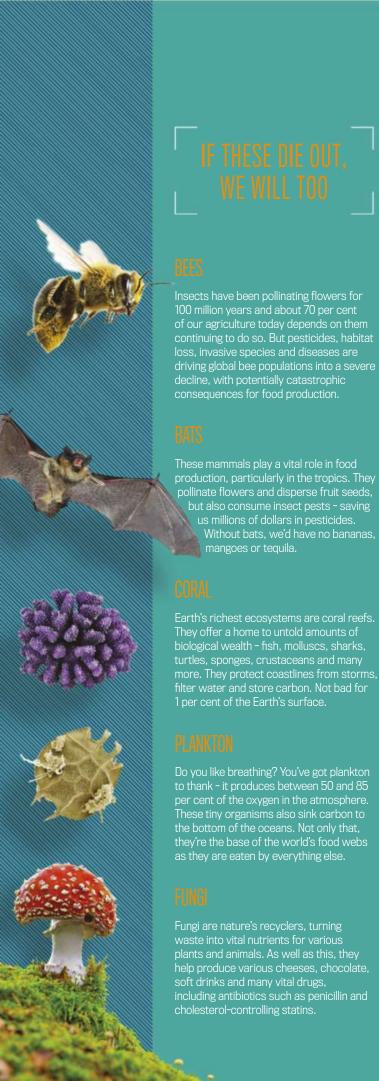


3 Finally, the seed samples are shipped to three separate places to ensure maximum security: the local gene bank, a second bank elsewhere in the world and Svalbard's global backup vault. This means that if one of the banks is destroyed, there will always be a backup.



6 For most crops, 75 per cent viability is the minimum requirement to pass the test, though for some grasses it can be as low as 50 per cent. If the seeds fail the test, a new sample is grown from the surviving seeds in a location as close as possible to their natural habitat.







When the Iron Curtain sliced Europe in two, wildlife flourished in the border regions because there was little human contact. Today, the European Green Belt aims to preserve and protect this environment

charitable foundations and other governments around the world. "It's definitely a long-term project but no-one can guarantee the funding," says von Bothmer.

NOAH'S ARK 2

It's not only plant seeds that are stored in gene banks – animal biodiversity is being cryopreserved in much the same way in almost a dozen 'frozen zoos' worldwide. One of the first was at the San Diego Zoo in the United States, where 8,400 samples from more than 800 species have been kept in liquid nitrogen since 1976. Stored material can be kept indefinitely and used for artificial insemination, in vitro fertilisation or cloning of animals in the future, although the network of global banks is nowhere near as comprehensive as that for plants.

Instead, animal biodiversity is mostly preserved alive, in the world's nature reserves. There are tens of thousands around the world and their protected status allows them to maintain ecological processes that have struggled to survive against the onslaught of human development. Several case studies have shown positive effects of these protected areas on plant and animal species, but many ecologists say they're not enough to combat biodiversity loss the scale we're seeing.

Dr Mark Steer from the University of West of England is one of them. "While nature reserves play a hugely important role in enabling some of our rarer species to cling on in largely hostile environments, our current system of protected areas is wholly inadequate if we want to maintain and enhance biodiversity," he explains. "If we cannot embed wildlife-friendly habitats throughout the wider landscape, creating



SAVING THE BLACK-FOOTED FERRET

SVALBARD MAY HAVE grabbed the headlines, but the US Fish & Wildlife Service has been working with a different kind of frozen seeds – using 20-year-old ferret sperm to improve genetic diversity in a strugging population of black-footed ferrets.

Once abundant on the Great Plains, by the early 1980s *Mustela nigripes* had been hunted to near-extinction. In a bid to save the species, the last 24 ferrets were rounded up and taken into captivity; six died, but captive breeding from

the remaining 18 has enabled the population to grow back into the hundreds. However, having such a small gene pool meant the population was becoming increasingly in-bred. So in 2008, the scientists reached for the frozen sperm samples stashed away two decades previously. Measures of in-breeding have since decreased by 5.8 per cent.

The positive outcome of the programme suggests that animal sperm banks could in future play a key role in maintaining Earth's biodiversity.



extensive and resilient ecological networks, then we will continue to see wildlife ebbing from our lives."

Some countries are, though, starting to build such embedded habitats. Wildlife corridors allow plants and animals to migrate between green spaces, joining up isolated populations and allowing them to find the resources they need to survive. One ambitious project is the European Green Belt, which hopes to turn the border that once formed the Iron Curtain into a green corridor that runs from the northernmost point of Europe down through more than 20 different countries until it reaches the Mediterranean Sea.

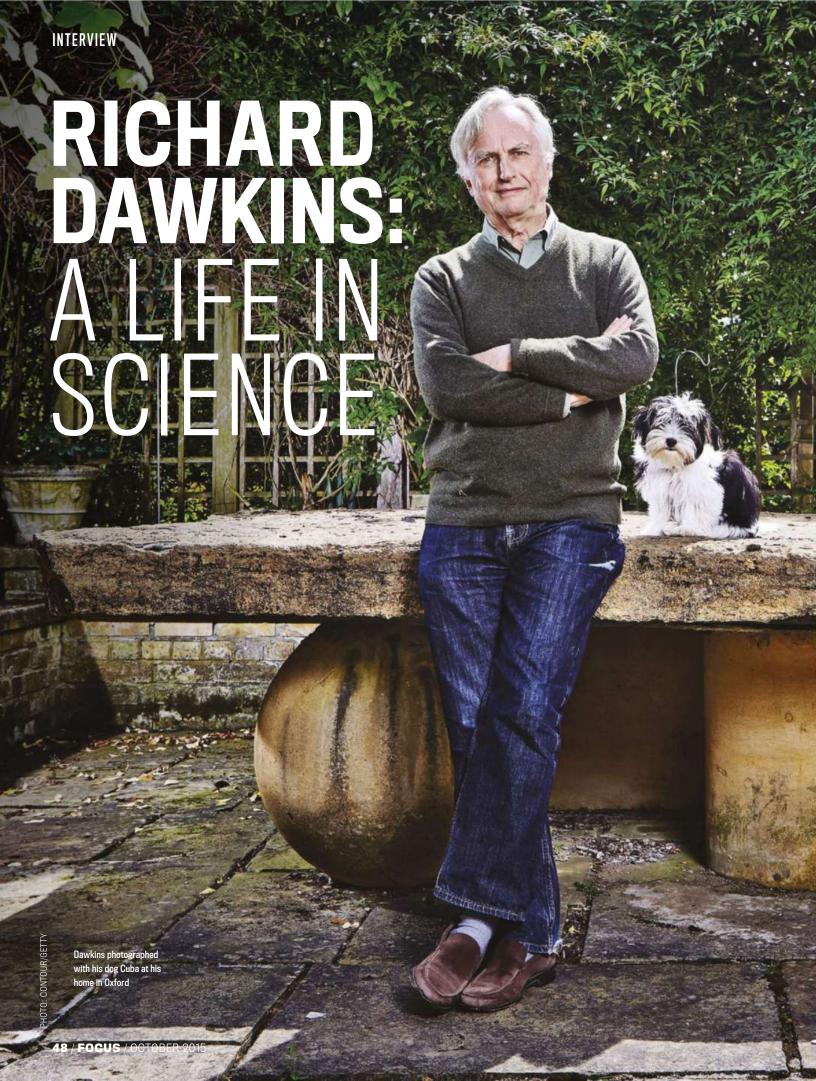
Ultimately, though, what we've accomplished so far is nowhere near sufficient to slow the pace of the mass extinction that's currently taking place all over the planet. Twenty elephants in a national park, or a handful of seeds on a shelf in an Arctic mountain, aren't performing their ecological roles, and the plant and animal populations that depend on them will eventually die unless profound change happens fast.

"We have to keep in mind that if the human enterprise – its level of population and consumption – continues to increase, if we continue to treat billions of people badly, either in terms of foodfroz or through prejudice and so on, then there's no hope," says Ehrlich. "Scientists who look closely at these issues know the direction we're going and the things we're not doing. The closer we get, the chances of being able to avoid it become diminishingly small. We should have taken action long ago." ■

DUNCAN GEERE is a freelance science writer based in Gothenburg, Sweden

DISCOVER MORE!

To read a BBC iWonder article about the origins of zoos and the purpose they serve, visit **bbc.in/1tpPbYu**



In his second memoir, *Brief Candle In The Dark*,

Prof Richard Dawkins

looks back over his illustrious career as evolutionary biologist, science evangelist and outspoken atheist.

James Lloyd met him in Oxford to talk evolution, aliens and hate mail

It's nearly 40 years since you published your first book, *The Selfish Gene*, and you've written 12 more since then. Which of your books are you most proud of?

Well, The Extended Phenotype is the only book I've written for a professional audience, so I am very proud of that. But if we're talking about books for a general audience, I think I'm most proud of Climbing Mount Improbable, which – funnily enough – is the book that's sold the least amount of copies.

What's Mount Improbable?

The metaphor of Mount Improbable is that you have a mountain with a sheer cliff face, and on the top of the mountain is the thing that's got to be evolved - the complicated adaptation, which might be an eye or something of that sort. It's impossible to leap from the bottom of the cliff to the top - that would be equivalent to all the parts of the eye coming together in one fell swoop. But if you go round the back of the mountain there's a gradual slope - it's easy to walk up the slope step by step, gradually increasing the perfection of the eye. Almost all of the arguments against evolution are from people who think it's about jumping from the bottom of the cliff to the top. But evolution walks slowly, one step at a time. And if you look around the animal kingdom, you do indeed find eyes at all stages.

What do you think has been your most influential idea?

I think that would be the extended phenotype, which is explained at

length in the book of that name. A phenotype is the effect the genes have on the body in which they sit – it's the physical manifestation of the genes. The genes that sit in the body of a bear or a wombat or a kangaroo survive by virtue of making the body in which they sit survive – genes don't survive naked. So everything about a bear or a wombat or a kangaroo is part of its phenotype.

So if a phenotype is the effect the genes have on the body they're in to improve its chances of survival, what's an extended phenotype?

This is the idea that the phenotypes by which genes survive don't have to be in the body in which the genes sit. A simple example would be an artefact like a bird's nest. The nest is made by the bird's

"I don't like deliberately stirring up controversy but there was no doubt that [*The God Delusion*] would be controversial"

behaviour – it's a complicated construction, exactly the right shape and you could easily see that natural selection will have shaped the nest to be better at keeping the chicks safe. The fact that the nest isn't part of the bird's body is what makes it an extended phenotype – you can say exactly the same thing about beaver dams.

You can then say: well, what about parasites? There are numerous beautiful examples of parasites that manipulate the body and behaviour of the host in which they sit. That's phenotype too.

For example, the so-called 'brainworm' parasite infects an ant in its early life, before moving on to a sheep or other grazing animals. Normally, in the heat of the day, the ant would go down into the ground. But the parasite fluke makes a lesion in the ant's brain that makes it

climb to the top of grass stems, meaning that the ant [and the fluke] is more likely to be eaten by a grazing animal. The behaviour of the ant is the extended phenotype of the genes in the fluke: natural selection is working on the fluke's genes to influence the phenotype of the ant.

Your early books focused on evolution but in 2006 you published *The God Delusion*. What made you decide to write a book about people's belief in religions?

I'd always had an interest in the philosophical implications of science and the idea of creation had always seemed to me to be incompatible with evolution. So I'd always had it in mind to bring together my thoughts on religion in a book. I proposed this to my literary agent John Brockman in the late 1990s and he more or less vetoed the idea because he said he couldn't sell it in America. I think it was probably George W Bush's presidency that changed his mind!

Did you expect *The God Delusion* to cause as much of a fuss as it did?

Oh, of course, yes. I don't like deliberately stirring up controversy but there was no doubt that it would be controversial. People are going to hit back when their most cherished assumptions are challenged.

You're often involved in debates with creationists. What's the argument that people most often use against the idea of evolution?

It's usually the idea that evolution is about chance or random luck. But the complexity, beauty and elegance of living things is so complicated and statistically improbable that it couldn't possibly come about by chance. This misunderstanding forgets that evolution is a cumulative process, where each step just builds in a minute, incremental way on the previous steps.

What would you say is the best evidence for evolution through natural selection?

I think the best evidence is comparative molecular biology. In Charles Darwin's time this wasn't



available but he made very powerful use of comparative anatomy, comparing the bones of, for example, the arm in lots of different mammals.

Today, the molecular equivalent is even more impressive because of the sheer quantity of data available. By comparing the genomes of different species, you can create an exact 'tree of cousin-ship' by literally counting the number of letters [of DNA] that they have in common. The molecular evidence is overwhelming in the case of chimpanzees – if you compare our DNA with theirs letter by letter, the chimpanzee-human resemblance is over 99 per cent.

In the face of so much evidence, why do you think so many people continue to reject evolution?

I think it's because of a number of things. One of them is human vanity – not wishing us to be 'mere' animals. Then there's the misunderstanding of randomness and also the inability to comprehend the vastness of time that's involved. [People that reject evolution might say:] "Well, when I see a monkey turning into a human...". But they're never going to see that, of course, because it takes much, much too long. People are used to the idea that a rabbit is a rabbit is a rabbit.

But I think the biggest reason of all is religion – many people are taught that evolution is false, and at an early, impressionable age. So they don't take kindly to anything they see that threatens [that belief].

What would you say is the most important question that evolution has yet to answer?

A very good candidate is the origin of life. Once you've got proper genes and something like DNA in place, which is a very high-fidelity replicator, then everything is explained – we understand the whole of life.

But we still need to understand how that first step was taken – [how we got to] the first self-replicating molecule. There are lots of theories and the truth probably lies somewhere around the ones we've already got but we may never reach a point that's any better



Ants, infected with the 'brainworm' parasite, are driven to climb blades of grass by the effect of the parasite's genes



Dawkins reads some of the hate mail he receives in clips on YouTube



than being able to say: "That theory's so elegant it's got to be true."

Speaking of life, what do you think are the chances of life existing on other planets?

Current estimates suggest there are 10^{22} stars in the Universe and we now know that many, many stars have planets orbiting them, so I think the argument [for life existing elsewhere] is statistically overwhelming. But if there are, let's suppose, only a billion other life forms in the Universe, they're likely to be spaced out over such vast distances that we're unlikely ever to encounter any of them, at least bodily.

"It wouldn't be that surprising to find, say, eyes or legs or wings on the organisms inhabiting another planet"

If there is life elsewhere in the Universe, do you think it will obey the same laws of evolution?

I would bet my shirt on any life on other planets being Darwinian life. Certainly nobody has ever suggested any alternative to natural selection as a way of getting the illusion of design. But it might be a very different kind of natural selection – it needn't be DNA necessarily.

If the world in which these hypothetical life forms are found is anything like ours, evolution could give rise to similar end results. We've already got a certain amount of indirect evidence for that – we've seen independent evolution of, for example, mammals in Australia, Eurasia and South America. And we've seen the same features cropping up again and again ever since the dinosaurs went extinct. So it wouldn't be that surprising to find, say, eyes or legs or wings on the organisms inhabiting another planet. There aren't that many solutions to the problems vision and movement pose.

Back on planet Earth, you're a prolific user of Twitter. Do you find that it's a good way to reach your fans?

I can't make up my mind. I'm kind of aware that I've got a very large number of followers – more than a million – so using Twitter does seem to be one possible way of getting a message out. But it's abundantly clear that the message is often misunderstood, and I think there's a bit of deliberate misunderstanding. So it's a double-edged sword.

There's a video of you on YouTube reading some of your 'hate emails'...

Oh yes – there are two actually. One with me by the fireside with a cat and one by a fish tank. They have generated an enormous amount of enthusiasm, I must say! A lot of people are very amused by them.

Does the hate mail you receive affect you at all?

Certainly not the ones that come from religious nuts – they don't worry me at all. I get a bit more upset by those that come from people who I think of as natural allies – people on the political left who misrepresent what I say as being bigoted or Islamophobic or that kind of thing.

And do you get fan mail too?

Yes – the ones that please me most are the ones from people that say, "you changed my life," of which I get a lot actually. Many people say they went to university to become a biologist as a result of reading *The Selfish Gene*, and that's immensely gratifying to me – I love that. And a lot of people say they were 'converted' by *The God Delusion*, or that they were already unbelievers but the book helped them to articulate it. I'm dead chuffed. ■

DISCOVER MORE!

Brief Candle In The Dark: My Life In Science is available to buy now (Bantam Press, £20)





TUNE IN TO TREATMENT FM

Music moves us to tears and drives us to dance. But as well as affecting our moods, it can also have a positive impact on our health. In fact, the more we learn about the power of music, the more applications we discover for it, as **Zoe Cormier** explains...

USIC IS MEDICINAL. You might expect a statement like this to come from someone in a drumming circle, a chanting crystal healer or sleazy record-label executive. But the idea that music can be used to heal the mind is increasingly grounded in scientific evidence – not theory.

Recent studies show how people coping with Parkinson's can learn to walk more easily when rhythms assist their gait. Other research suggests autistic children find social interactions become easier when accompanied by music, and that less anaesthetic is required when music is played to spinal surgery patients. Perhaps most astoundingly, premature babies gain weight quicker when they can hear music.

Scientific studies – ranging from investigations of the brain at a cellular level, to psychiatric assessments of schizophrenics, to linguistic scores in stroke patients – are all leading to the same conclusion: music isn't just a form of entertainment, it is evolutionarily significant. And the more we learn about the impact of music on the brain, the more we understand how it can be employed as a therapeutic intervention.

SO MUCH TO LEARN

"I originally trained as a music therapist but when I went into practice 15 years ago, I found that so little formal research had been done on how or why it works," says Prof Christian Gold of the Grieg Academy Department of Music at the University of Bergen in Norway. Gold studies how music therapy can help people with a wide variety of conditions, ranging from learning disabilities to schizophrenia and dementia. "I had planned to go back into clinical practice after spending a few years in research but 15 years later, I'm still researching. There's just so much to learn."

Perhaps the most familiar notion of the power of music is the claim that listening to Mozart is good for your brain. But that only tells half the story. Listening to classical music (or any kind of music, for that matter) does have quantifiable impacts on aspects of cognition, such as visual puzzle solving. However, everything you do – solving puzzles, playing sports, painting landscapes – has an impact on your brain.

But nothing seems to anatomically, chemically and beneficially alter your brain the way music can. The grey matter, which is the outer layer of the brain that contains the synapses – the ends of the neurones where signals are relayed – thickens with musical training. Furthermore, the cerebellum, which is the wrinkly bulb at the back of the brain that's crucial for balance, movement and motor control, is bigger in pianists.

Neuroscientists have documented many other anatomical changes that come with musical experience but the most profound is thought to be the fact that the corpus callosum – a band of nerve fibres that connect the left and right hemispheres to each other – thickens. No-one is quite sure what helping the two sides of the brain to communicate with each other accomplishes, but 20 years after this discovery, nobody has found anything else that does this.



What's more, MRI scans and EEG recordings show that playing – or even just listening to – music engages almost every region of the brain. From top to bottom, front to back, every part of the brain is involved in the process. The newest parts of the brain, such as the frontal cortex, which is associated with higher thinking, tune in. Older structures in the middle, such as the hippocampus (crucial for memory formation) and the amygdala (central to fear and emotion), are also stimulated by the sound. As are even older parts of the brain, such as the cerebellum. Even the brainstem, the most prehistoric part, responds to music – but not to spoken language.

As far as we know, nothing engages as many parts of the brain as music, which suggests that it might have played an important role in our evolution.

LOST FOR WORDS

What came first: language or music? Neuroscientists – including Steven Pinker – once thought that language was the crucial skill on the CV of the

WHY MUSIC MAKES US TINGLE

Sound can cause physical reactions in powerful ways

Purring cats relax us and explosions shock us. But music can do something even more extraordinary: exhilarate us. And it's only in the last 15 years that neuroscientists have been able to reveal why. For one, listening to music can stimulate ancient parts of the brain involved in reward and pleasure. But more importantly, a complex sequence of events result in the release of the neurotransmitter dopamine by a part of

Get tingles up your spine when listening to Nickelback? Thank dopamine for that - just don't tell anyone about it

the brain called the nucleus accumbens. The nucleus accumbens releases this pleasure chemical in response to sex, drugs and music, but not to random noises. Once flushed into the bloodstream, dopamine can make tingle us from the top of our heads to the tips of our toes. What's more, music also triggers the release of other neurotransmitters such as endorphins, serotonin and vasopressin. Music is an auditory chemical cocktail – with no hangover.

BEATS FOR BEASTIES

Do animals make music? It's a difficult to say for certain. Many animals use complex forms of communication, but does that qualify as music?



A study published earlier this year in the journal Frontiers In Behavioral Neuroscience found that male mice 'sing' in ultrasonic frequencies (sounds too high for our ears to detect) to attract females. What's more, the researchers from Duke University found that the rodents produce more complex calls to attract females they have never met but whom they have sensed by smelling traces of their urine.



GIBBONS

Most animals vocalise in some way. But to be considered musical, scientists argue, the animals need to display vocal learning: they must have to learn how to sing in a specific way throughout their lives. Gibbons certainly do: male and female pairs duet loudly every morning to defend their territory. And it's a skill they have to learn: a 2013 study described how gibbon mothers teach their daughters to sing.



WHALES

Until 1967, humans had no idea that whales make complex songs with phrases, repetitions and codas. Now we know that whale songs change over time and vary between populations, indicating that whales have culture. We can also use whale song to identify new species. This year, in Marine Mammal Science, scientists described a recording from Antarctica, which could be from a species of beaked whale unknown to science.



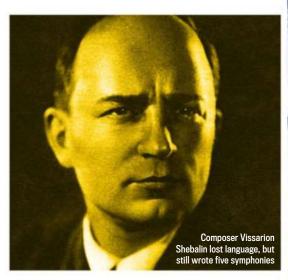
NIGHTINGALES

If any species of animal produces 'true music', it's most likely to be a bird: no other class of creatures produce sonic compositions that are so varied - or so sweet. Birds use songs to defend territory, attract mates, practise riffs and show off. In 1924 a nightingale spontaneously joined cellist Beatrice Harrison for the world's first outdoor broadcast for an impromptu duet. (Listen here: bit.ly/1MKTuG7)



COCKATOOS

It's undeniable that animals create complex, meaningful noises. But do they have rhythm? Neuroscientist Ani Patel claimed only humans can keep a beat. And he was proved wrong. Snowball - tested in his lab - bopped to Michael Jackson, Backstreet Boys and Queen in perfect time, even when the tempo was sped up or slowed down. The cockatoo became the first animal immortalised in a scientific paper for his groove.



human brain and the characteristic that set us apart from other animals. He called music 'auditory cheesecake' - meaning that we like structured noises because they exploit the same networks in our brains that are built to process grammar, prosody and other speech patterns.

But not only does music engage parts of the brain that are not stimulated by language, it is possible to be musical and completely non-verbal. Aphasia – the loss of speech comprehension or production - frequently occurs following a stroke and can leave many people unable to speak and thus feeling isolated and depressed. Yet often those who can't speak can still appreciate and create music. The most famous example of this is the Russian composer Vissarion Shebalin (1902-1963) who developed aphasia after a series of strokes. He couldn't speak, yet he could still craft entire symphonies, completing his fifth and final one just three months before his death.

Worldwide, 15 million people suffer strokes every year and speech difficulties are one of the most common outcomes. Therapists in the 1940s began developing a technique known as melodic intonation therapy - using melodies and singing to help stroke victims regain speech. The idea made sense; after all, young children learn the alphabet through song and 'motherese' - the

"MRI and EEG scans show that playing - or even listening to - music engages almost every region on the brain"

CORBIS, STR NEWS / REUTERS

GETTY, (

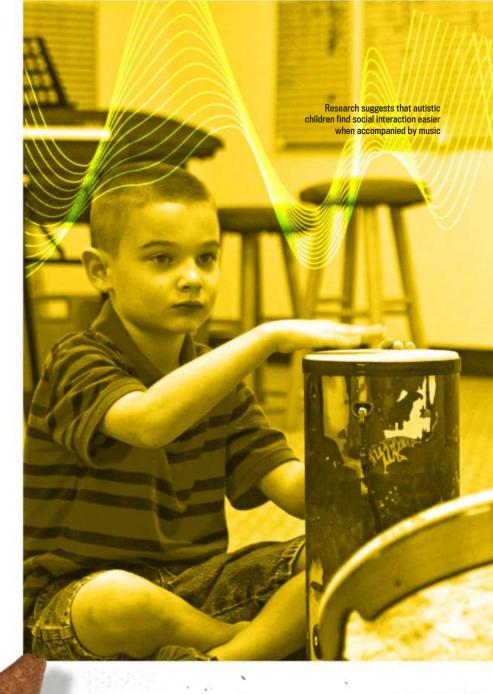
sing-song language that parents coo to their babies that is found in every culture on Earth. Neuroscientists theorised in the 1970s that when a stroke damages areas in the left hemisphere of the brain that are crucial for language – in particular, Broca's area – musical training can cause regions on the undamaged right hemisphere to take on the task of producing speech instead.

Since then countless studies have documented how music can aid speech recovery. The highest profile example of this is probably US congresswoman Gabrielle Giffords. She was shot in the head in 2011 but survived the attempted assassination. She credits music therapy for helping her regain the ability to read, write and speak.

"Although it's still an open question over what aspects of music are important – rhythmic or melodic – there is growing evidence that melodic intonation therapy can help people with aphasia," says Dr Teppo Särkämö of the University of Helsinki. Through examining MRI scans of stroke patients he has shown not only that music aids in language recovery, but actually induces visible changes in a variety of brain structures after just six months of treatment.

In 2008, Särkämö found that of 54 stroke patients, those given musical recordings improved in their linguistic capacities to a greater degree than patients given audio books. Music aided language recovery better than language itself.

"One of the things that makes music so interesting is that it's pleasant but at the same time cognitively demanding," says Särkämö. "This is one of the few therapeutic interventions we have that is both soothing as well as challenging."



THE WORLD'S OLDEST INSTRUMENT The 43,000-year-old Divie Babe flute is one

The 43,000-year-old Divje Babe flute is one of the oldest human creations ever found. It's an 11cm-long piece of a bear's femur, with two fingertip-sized holes spaced 3.5cm apart. Due to its similiarity to modern wind instruments, it was dubbed the 'Neanderthal flute' by the archaeologists who found it in Slovenia in 1995. Reconstructions indicate it could play the musical scale.

THE WORLD'S OLDEST AUDITORIUM

Prehistoric cave art in Arcy-sur-Cure, France, dated to 30,000 years old, is visually impressive. But to add to this, acoustic analysis shows that the scenes depicting bison, horses and hunting were frequently painted in subterranean areas that have the best acoustic properties for resonance and reverberation. This suggests they were used as the backdrop to musical performances, like an ornamented concert hall.



THE WORLD'S OLDEST SONG

A Sumerian hymn (pictured right), inscribed onto clav tablets in Mesopotamia and recovered in Syria in the 1950s, has been estimated to be 3,400 years old, making it the oldest written song. However, to call it the 'oldest song' is a bit of a misnomer: epic ballads were passed on orally for thousands of vears before the invention of writing.

Music can also be used to help patients who have never been able to speak in the first place, such as people with Rett syndrome. "Because they don't tend to speak at all, we struggle to understand what they may be thinking or feeling," says Gold, whose own research has measured how music stimulates the brainstems of people with Rett syndrome. "This seems to be an important indicator of the effects that music therapy may be having on them – relaxation or excitement."

Severe impairments such as Rett sysndrome are not the only childhood conditions that music therapists target: 12 per cent of clinical work with autistic children in the UK involves music in some way, most commonly in helping them interact with others.

"It makes sense because music is ultimately about social interactions," says Gold. "In musical communication, if you improvise with somebody, there are subtle adjustments you have to make when you interact with them. Those social









THE WORLD'S OLDEST SHEET MUSIC

Engraved onto a marble column in Turkey by the ancient Greeks around 100AD, the Seikilos Epitaph (pictured right) is the oldest complete musical score known. Older fragments of sheet music have been recovered but only this piece retains the melody and lyrics, including this sentiment: "While you live, shine/Have no grief at all/Life exists only a short while."



This ancient instrument is made from crafted stones that make a resonant noise when struck, and has been dated to between 2500BC and 8000BC. In one French cave system, however, there could be an even older 'xylophone'. Ochre markings placed on stalagmites appear to pinpoint spots that produce different notes when struck. What's more, the pillars are dented on the marks, and around them lie shards of bone, presumably chipped off prehistoric drumsticks.



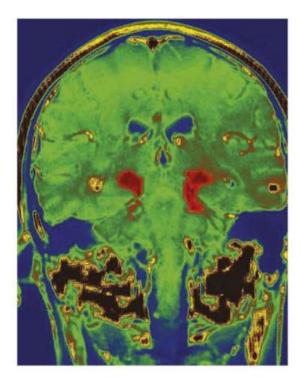
exchanges are the most important part of most forms of music therapy."

Humans are social creatures that require social contact. Few experiences can be more isolating than the impairments of ageing, so it's not surprising that this is one of the oldest and most established areas of research in music therapy.

Take, for example, the tremors and mobility problems that come with Parkinson's: "People with disorders that cause tremors tend to fall. Though medication can help with the tremors, there is little that can be done to help them regain the ability to walk," says Prof Simone Dalla Bella from the University of Montpellier. With metronomes and percussive instruments, he studies how melodic gait therapy can help Parkinson's sufferers walk more steadily. Similar to the way that soldiers learn to march to a drumbeat, Parkinson's sufferers can improve their walking with the help of a rhythm.

"The fascinating thing about this therapy is that the benefits are not confined to gait – we also see improvements in things like motor control," says Dalla Bella. "Patients who are given auditory cue training, for example, can greatly improve in their perception of and ability to produce speech."

The mechanism by which music helps Parkinson's patients appears to lie in a region of the brain called the nucleus accumbens. This is the same region that releases dopamine – the neurotransmitter associated with pleasure – in response to chemical stimulants like drugs, or physical stimulants like sex.



Parkinson's causes parts of the brain to degenerate



Lost Chord's founder Helena Muller helps dementia patients to enjoy live music

Parkinson's is characterised by an impairment of the connections between a cluster of brain structures called the basal ganglia and other regions due to a lack of dopamine. So it makes sense, says Dalla Bella, that if music can trigger the release of dopamine in that region, it would be helpful.

MUSICAL MEMORIES

Of all the afflictions of old age, none could be more isolating than Alzheimer's: memories are left behind, loved ones are forgotten and whole identities are gradually lost. More than 25 million people in the UK are affected, by knowing somebody who has dementia.

"We don't have a cure for Alzheimer's and there is no cure on the horizon: we need to work on ways to make the sufferers' lives, and the lives of their carers, easier," says psychologist Dr Victoria



Williamson of the University of Sheffield, author of *You Are The Music*. "Music is not a pill or a vitamin or a cure, but it can provide powerful support, alleviating real symptoms like depression and anxiety. There is no reason not to invest in providing music to as many people living in care homes as possible."

After spending many years in the lab studying musical memory, Williamson began working with the charity Lost Chord. Lost Chord was set up in 1999 by Helena Muller to provide live music in residential care homes for people with dementia. "People regularly describe the Lost Chord memory cafes as their lifeline. People can revert back to being a couple again rather than carer and person with dementia. The benefits gained by the people with dementia is immeasurable. To observe people who are withdrawn and isolated come out of their shell and engage by singing and dancing is tangible,

powerful and emotional for all to see," says the Alzheimer's Society.

"The choir at the Lost Chord memory cafe is one of the few things that makes him smile," says Marion Jones, whose husband has severe Alzheimer's.

The deep hold that music can have in our memories is perhaps best exemplified at events like the Lost Chord memory cafes. Even when people with advanced-stage dementia can't remember the names of their children, they can recall lyrics from the songs of their childhood. Recent neurological studies have verified and scrutinised this, with important findings.

"It is important that we work to provide live music to people in care homes, and not simply give them iPods to sedate them," says Williamson. "Why would an isolating condition be alleviated by an isolating device?"

"Patients who are given auditory cue training, for example, can greatly improve their ability to speak"

This brings us back to what music, ultimately, is: a form of social navigation via sound. As it involves so many ancient brain regions, and can be used in so many therapeutic ways, is music something we are 'hardwired' for?

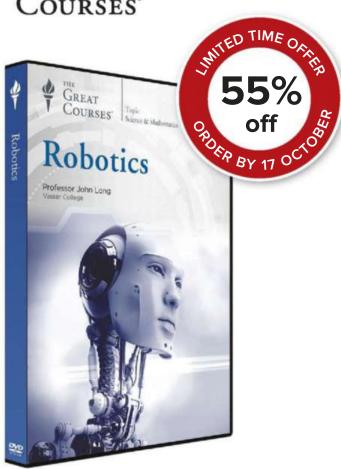
"I used to think so – but the more I learn about music, the more I think it's not something we inherited: I think it is an invention. Yes, our brains are pre-programmed to be able to produce music. But music didn't make us – we made it," says Williamson. "We began making music because it fulfilled so many useful purposes: communication, social bonding, teamwork, sexual attraction. It's a ball we just can't put down. This is the best invention we ever came up with."

ZOE CORMIER is a freelance science writer and author of Sex, Drugs & Rock 'N' Roll: The Science Of Hedonism

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Deciphering space is tricky – after all, you can't shove a planet in a petri dish. But as **Colin Stuart** reveals, a new computerised cosmos could revolutionise astronomy as we know it

STRONOMY IS UNIQUE among the sciences as it is conducted at a distance. Geologists can go out in the field to study rocks face-toface and even bring them back to the laboratory for further analysis. The same goes for biologists, palaeontologists and chemists - they're all very hands-on. But what if your area of interest lies in galaxies and how they evolved to form the structure of the known Universe? What do you do then? You can't haul a galaxy down to Earth for closer inspection and telescopes only provides a snapshot of what they were like at for a brief moment. For a group of astronomers based in Durham and Leiden, in the Netherlands, the answer is to build a replica of the Universe in a supercomputer.

Their brainchild is the EAGLE (Evolution and Assembly of GaLaxies and their Environments) project. This virtual reality universe consists of an enormous cosmological cube measuring more than 300 million light-years on each side, enough to contain around 10,000 galaxies like our own Milky Way.

To construct it, the team went right back to a time before the first galaxies, and even the first stars, formed. Three main players governed the evolution of our Universe at this time: dark matter, normal (baryonic) matter and dark energy. Dark matter acted as an invisible scaffold around which the structure of the Universe developed. Dense regions of dark matter created gravitational dimples into which more and more normal matter flowed as the Universe aged. This material was drawn together to form stars, which then

coalesced to form galaxies. Dark energy is the unseen force that tries to resist dark matter's natural desire to clump together over large distance scales.

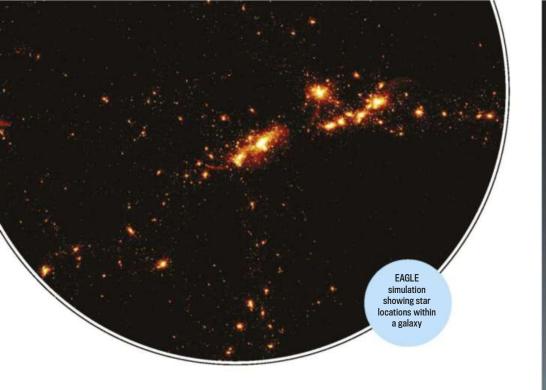
Previous computer simulations of how the interaction between these processes form galaxies haven't always worked. "They tended to produce galaxies that were far too big and therefore a Universe with far too many stars in," says Prof Richard Bower, part of the EAGLE team at Durham University. So using the latest data on those three key ingredients from missions like the European Space Agency's Planck satellite wasn't enough, the EAGLE simulation also had to factor in the latest thinking on how galaxies evolve from youth to maturity.

Doing this required modelling how exploding stars and marauding black holes affect the development of the structure of the galaxies in which they reside. Translating all these aspects into a suitable computer code took Bower and his team three years, but the time-consuming work didn't end there. Running that code through the DiRAC-II supercomputer to create the simulated universe took more than a month and a half of solid computing time. But the results were remarkable. "It is incredible

"It is incredible how much a simulated galaxy in EAGLE looks like the real thing"

Prof Richard Bower, EAGLE team member



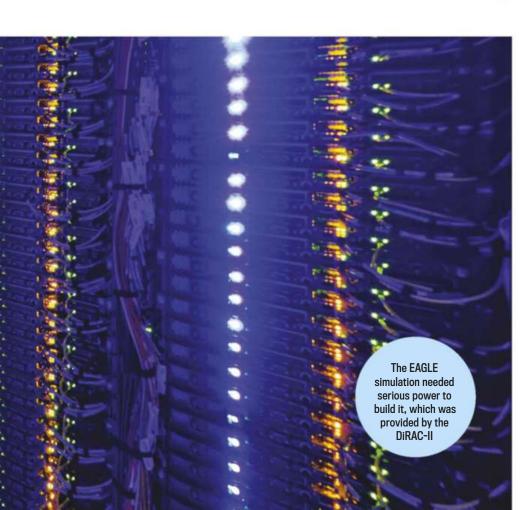


how much a simulated galaxy in EAGLE looks like the real thing," says Bower. "I give talks in which it takes people five minutes to twig that they're looking at a simulated image rather than a real one."

STAR SYSTEM

An accurate computer counterpart to the real Universe is a powerful tool. You can take any galaxy and hit what Bower describes as "the big red button" to travel back in time and follow the evolution of that galaxy from its earliest days, revealing how it ended up in its present state.

Theories for galaxy evolution that do not match what EAGLE shows can be discarded. It also has the ability to clear up mysteries. When astronomers use telescopes to look at distant objects, they're looking into the past, seeing light that has been trekking across space for billions of years to get here and bringing information about what its



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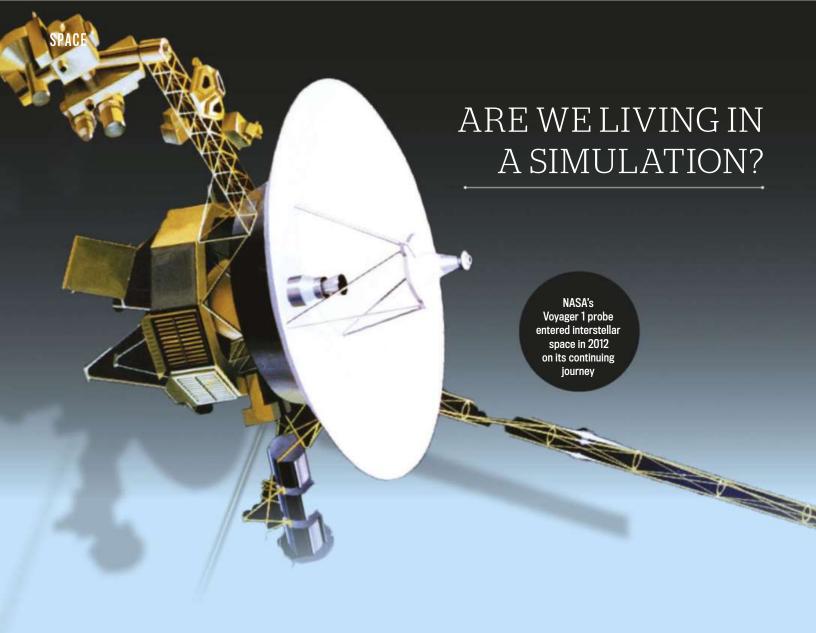
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MOST POWERFUL SUPERCOMPUTER IN THE UK (AS OF 2012)



IN THE 1998 film *The Truman Show*, Jim Carrey plays Truman Burbank (below right), a man unknowingly living in a fake town that's been simulated for the purposes of a reality television show. As far as he's concerned his life is real, but his family and friends are all played by actors - even the weather is controlled by the show's producers. He eventually discovers the ruse when he sails a boat into a wall in the middle of what he thinks is the ocean while trying to escape. Over the years many scientists have wondered whether we exist in a similar situation perhaps we are living in a simulation created by a more advanced civilisation.

It's easy to dismiss such an idea as ludicrous, but it is not as wild a notion as it first appears. It would, in a stroke, solve the fine-tuning problem and explain how come our Universe came to be

perfectly set for life – simply because someone designed it that way. In 2001, Stephen Baxter published a paper detailing what he called the Planetarium Hypothesis. It basically argues that our entire existence, including what we see as our Universe, could be a giant

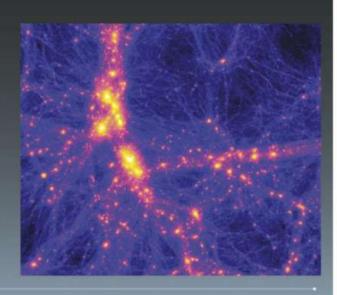


simulation. He was able to show that a very advanced civilisation would be able to create a perfect simulation with a radius 100 times bigger than the distance from the Earth to the Sun.

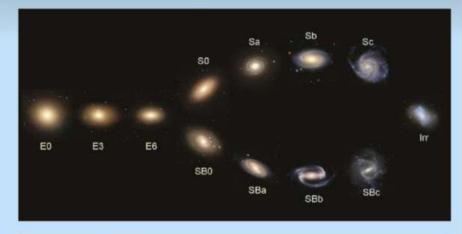
Since Baxter's paper, the Voyager 1 spacecraft has exceeded this distance and didn't crash into a wall like Truman. Of course, the possibility that we live in an imperfect simulation is still open. And if it is imperfect, we might one day be able to expose the simulation. In 2012, a team led by Silas Beane published a paper entitled Constraints On Universe As A Numerical Simulation in which they show that "in principle, there always remains the possibility for the simulated to discover the simulators." Beane and his colleagues have even suggested that there might a way of glimpsing the boundaries of the simulation by looking at cosmic rays - the astronomical equivalent of a glitch in the Matrix.

INSIDE EAGLE

Here is the Universe on the largest scale from within the EAGLE simulation. You can see the tentacle-like filaments of normal matter strung out on an invisible scaffold of dark matter. As the Universe aged, normal matter was drawn towards the dark matter until it coalesced into stars. then galaxies.



The simulation created all types of galaxies, not just grand spirals like the Milky Way. Astronomers classify galaxies according the Hubble 'tuning fork' diagram, pictured below. It shows elliptical galaxies on the left, lenticulars in the middle and the spirals to the right. Galaxies within EAGLE also followed this pattern.





The EAGLE simulation encompasses 10,000 galaxies similar to our Milky Way, contained within a volume that's 300 million light-years wide on each side. The large image on the left shows one of these beautiful galactic analogues with its bright centre of old, yellow stars and sweeping dust lanes picked out by bright, young blue stars. The smaller image is a computer graphic of our own Milky Way.

source was like at that time. It's a well-established fact that the early Universe contained many red and very compact galaxies. But these red galaxies seem to have disappeared as the Universe evolved because we don't see them any more. This vanishing act is also seen in the EAGLE simulation. Unlike with telescopes, astronomers using EAGLE can wind the clock back and keep tabs on these galaxies to see what happened to them.

It turns out that in most cases these small red galaxies merge with galaxies that are much bigger than they are.
"EAGLE is telling us something important about the Universe that we couldn't know

"The simulation is shedding light on a long-standing mystery surrounding the rate at which stars form"

any other way," says Bower.

The simulation is also shedding light on a long-standing mystery surrounding the rate at which stars form in galaxies. When astronomers look out into the Universe they notice that galaxies bigger than the Milky Way have very little star formation, whereas galaxies smaller than ours seem to be making new stars at a relatively impressive rate. It has long been suspected that this has something to do with our galaxy's central black hole. The bigger the galaxy, the more rapidly the black hole forms, which doesn't lead to a lot of stability for star formation. In smaller galaxies, the black hole seems to grow at a more sedate pace, giving stars time to form. Yet the reason why black holes grow faster in larger galaxies was

"The effect of dark energy is that it increases the computing time required to run the calculations"

Prof Richard Bower, EAGLE team member

unclear. Now, by looking at the simulated galaxies in EAGLE, researchers can see exactly what is going on. As larger galaxies contain a lot more material, gas near the centre is prevented from flowing outwards. With the rich supply of food this extra material provides, the black hole is able to gorge more effectively. "This shuts down star formation in the galaxy," says Bower. "Understanding this process is a huge step forward in our knowledge."

After using the simulation to travel back in time to provide some valuable insights, the team are now setting their sights on the future – using EAGLE to see what lies in store for our Universe. This is a much trickier task than going backwards, however. And to understand

why, we need to return to the key players in the evolution of the Universe: dark matter and dark energy.

As the Universe has been expanding, and the galaxies have been moving further and further apart, the collective force of dark matter has been gradually dwindling. The strength of dark energy, however, has remained constant throughout the Universe's history. This means that there came a time when the attractive strength of dark matter dropped below that of repulsive force of dark energy. At this point the expansion of the Universe began to accelerate. It is this acceleration that makes modelling the future in EAGLE difficult.

"The effect of dark energy is that it increases the computing time required

to run the calculations," says Bower. And that makes it almost a prohibitively expensive project.

However, Bower and his colleagues are hopeful they can find a way to do it. They are already working with Intel, the American computer-chip manufacturer, to incorporate their next generation of processors. If they can get the maximum efficiency out of the new chips, it should provide a tenfold increase in the speed of their calculations. Bower's team is also looking to upgrade the supercomputers and that will lead to a further increase in the computing power at their disposal. They could then boost the size of the simulation from the 10,000 Milky Waylike galaxies it currently contains to 30,000. With a much larger set of galaxies, they could begin to do serious statistical analysis to determine how rare a galaxy like ours really is.

CRAZY PROJECT

Yet Bower wants to go even further, with what he describes as his "crazy project". He'd like to use EAGLE to see just how special our Universe is. For many years astronomers have encountered a 'finetuning problem'. When you look at the fundamental constants of the Universe the strength of gravity, the amount of dark energy and so on - everything seems eerily balanced. Say there was more dark energy. That would have accelerated the expansion of the Universe at a much earlier time, leaving dark matter no chance to gather all the normal matter into stars and galaxies. How come with all of the values these cosmological parameters can have, they seem to be just right to give rise to a Universe capable of supporting life?

One answer is that our Universe isn't the only one. If there were other Universes, and the parameters were set slightly different in each one, then of course we're going to find ourselves in the Universe with the right combination for stars, galaxies, planets and people. We could hardly live in one with the wrong settings. Bower hopes to use EAGLE to discover exactly how changing these initial conditions affects how a universe turns out, once again providing an insight into how we came to be.

In many ways, the success of the EAGLE project represents a watershed moment. It marks the point at which supercomputers have become as important to astronomers as telescopes.

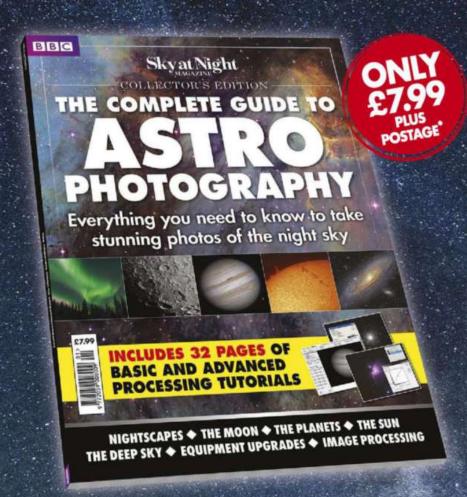
There is far more dark matter (top left) in the simulated universe than visible matter (bottom right), just as in our own Universe

COLIN STUART is an astronomy writer and co-author of *The Big Questions In Science*

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THINGS YOUR FACE SAYS ABOUT YOU

The eyes may be the window to your soul but your face, features and complexion give away all sorts of information about you. Christian Jarrett investigates

HOW MUCH CHOLESTEROL YOU HAVE

"MIRROR, MIRROR ON the wall, who's the fittest of them all?" Asking this very question might become a commonplace occurrence following the

announcement this summer that a mirror is in development that will assess the health of anyone who looks into it.

The Wize Mirror is being developed by researchers from seven European countries, coordinated by the National Research Council of Italy. The device uses five compact cameras and a 3D scanner to measure facial skin tone, the amount of fat on the face and facial expressions. It also analyses breath. Based on this data, the mirror estimates factors such as cholesterol levels, glucose levels, anaemia, weight gain and stress. If you're looking a little run-down, the idea is the mirror will provide you with tailored health advice to get fit again.

Right now, the mirror is still only at a prototype stage. For a more immediate estimate of your longevity, find some old photos of yourself and see if you're smiling. A recent analysis of baseball photos in a 1952 register found that of the players who'd since died, those pictured with a genuine smile had lived to age 80, on average, compared to an average age of 73 among the non-smilers.



Baseball players who smiled on their photos lived longer than those who didn't



"MEN WITH BROWN
EYES ARE PERCEIVED
TO BE MORE DOMINANT
THAN MEN WITH
BLUE EYES"



HOW TRUSTWORTHY YOU ARE

WE ROUTINELY make assumptions about each other's traits based on facial appearance.

Sometimes these inferences are made quickly, suggesting that we can gather significant clues in a split second.

Generally, faces that are babyish (think less pointy, with a high forehead) are rated as more trustworthy. Other face-based character assumptions appear at first to be tied to specific facial features, but the reality is more complicated. For example, there's evidence that men with brown eyes are perceived to be more dominant than men with blue eyes. But when a blue-eyed man dons brown contact lenses, this does nothing to increase how dominant he appears

to strangers. This suggests there's something else about brown-eyed men that creates an impression of dominance.

There's some recent evidence that we can overcome the personality signals given off by our static facial structure, simply by pulling the right facial expressions. Psychologists call this 'social camouflaging' and it was demonstrated in a study published last year by researchers at the University of Glasgow. An animated face morphed to look optimally untrustworthy based on its basic structure was rendered trustworthy by programming it to pull a facial expression that involved raising the lips and cheeks. "Social camouflage of dominance and trustworthiness is probably commonplace in everyday interactions," the researchers explain.



Brown-eyed men are viewed as more dominant than their blue-eyed friends

WHAT MOOD YOU'RE IN

3

SINCE CHARLES DARWIN first compared the emotional displays of humans and animals, it's been argued by many experts that humans exhibit six basic emotions via six core facial expressions: happiness, surprise, fear, disgust, anger and

sadness. No-one disputes that facial movements convey what we're feeling, but there is some debate over the cultural universality of the emotional expressions.

At the recent Royal Society Face Facts exhibition, researchers from the University of Glasgow presented their evidence that the interpretation of emotional facial expressions is not, in fact, universal. They used a unique 3D computer system to create digital avatars that could

independently manipulate all 42 muscles in the face. The researchers then presented participants from a Western or an East Asian background with these avatars showing random combinations of facial muscle movements, and the participants had to say when they recognised one of the six basic emotions. There were

differences in how the Westerners and
East Asians responded – for example, the
East Asians were a lot less consistent in
how they categorised some emotions
(especially surprise, fear, disgust and
anger), and saw movements of the
eyes as more important for interpreting
emotional intensity.

Quoting Darwin, the researchers say: "Although some basic facial expressions such as fear and disgust originally served as an adaptive function when humans 'existed in a much lower and animal-like condition', facial expression signals have since evolved and diversified to serve the primary role of emotion communication during social interaction."



"NO-ONE
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East Asian people tend to rely more on eye movements when interpreting expressions

HOW WELL YOU FIGHT

THE SHAPE OF your face is related to your fighting prowess – if you're a man.
Psychologists made this discovery in 2014 after analysing photographs

of over 200 mixed martial artists in the Ultimate Fighting Championship (UFC). Male fighters with faces that were wider relative to their length tended to win more fights, and the association held even after factoring out the influence of body size. The result chimes with past research linking facial width with aggression. What's more, it seems we intuitively know that this facial characteristic is a marker of pugilistic prowess. When the researchers manipulated fighters' photos to make their faces appear wider, this led observers to rate the fighters as more deadly.

Another temporary facial cue to fighting ability is a smile. Across the animal kingdom, it's common for a smile to be used as a signal of submission. Consistent with this, a 2013 study of UFC fighters published in the journal *Emotion* found that those who smiled at a pre-match face-off were more likely to lose the ensuing confrontation. "Smiles appear to play a unique role in physical confrontations, as a sign of a person's reduced physical dominance," the researchers say.



PHOTO: GETTY, UC SAN DIEGO SCHOOL OF MEDICINE, UNIVERSITY OF NOTTINGHAM, SHUTTERSTOCK

WHAT YOU'RE REACTING TO

had just happened to someone from a short, silent video of their facial reaction? Specifically, could you tell whether they'd been told a joke, heard been made to wait for five minutes?

This is exactly the challenge that

University of Nottingham psychologists gave their participants for a study published in 2012, which each other's racial expressions than simply naming the emotion on display. The participants averaged around 60 per cent accuracy – not great, but if they'd just guessed each time, their accuracy would only have been 25 per cent. Accuracy was especially high (90 per cent on average) for recognising when someone had been made to wait. In general, participants who were more accurate tended to focus more on the mouth region. The researchers say: "From observing just a few seconds of a person's reaction, it appears we can gauge what kind of event might have

happened to that individual with considerable success."



WHETHER YOU'RE ARTY OR SCIENTIFIC

we turn to face the camera for photos. However, an analysis of thousands of university academics' homepage photos suggests there's more to this than vanity. Engineers, mathematicians and chemists more often posed with their right cheek forward, while arts scholars and psychologists more often posed with their left cheek showing. There was also a gender difference, with female academics more likely to display a greater amount of their left cheek.

MANY OF US have a side of our

face that we prefer, and that

The research, led by Owen Churches at the University of South Australia (incidentally, his web photo shows more right cheek) says that the findings were consistent with past work suggesting that more emotionally expressive people tend to pose with the left cheek on display, and that naive observers assume right-cheek posers are more scientific.

"Academics be warned," the research concluded, "We present ourselves to our students and colleagues in our profile pictures, and the way we do so may reveal more about ourselves than we think.'



"THERE WAS A GENDER DIFFERENCE, WITH FEMALE ACADEMICS MORE LIKELY TO DISPLAY A GREATER **AMOUNT OF THEIR LEFT CHEEK"**



WHAT LIFESTYLE YOU LEAD

SOME PEOPLE CERTAINLY seem to have more 'lived-in' faces than others. This year, researchers at the Chinese Academy of Sciences elaborated on this principle, reporting that they'd used computer imagery to generate 3D models of over 300 people's faces (aged 17 to 77), and that they'd used these models to look for correlations between specific facial features and age. For example, older people tended to have wider noses and more sloping eyes. Some people had faces that were 'young' for their age based on these markers, with any two people of the same chronological age differing by around six 'face years' on average.

Facial age correlated more strongly with objective markers of health, such as cholesterol levels, than with chronological age - showing that a person's lifestyle is indeed written in their face.





In the picture on the left the boy is suffering ongoing pain, on the right he is suffering transient pain - the difference in his facial expression is clearly visible

HOW MUCH PAIN YOU'RE IN

IT'S OFTEN DIFFICULT for people to articulate their pain, especially children.

Thankfully, researchers at the University of California recently announced that they've created a computer algorithm that decodes videos of children's changing facial expressions to determine how much pain they're in. The algorithm was tested on children aged five to 18 who were recovering from appendix surgery, and its estimates of their pain correlated well with their self-reports – better, in fact, than the estimates made by nurses.

An advantage of this technique is that it could provide a continuous measure of a patient's pain. Scheduled assessments, by contrast, can miss those times when a patient is suffering the most. Moreover, the computer program is not biased by a patient's age, gender or ethnicity, and could be used for children who are too young to communicate how much pain they're in.





While participants could not distinguish politicians' affiliation, their perceptions were then used to create 'perfect' Labour and Conservative MPs (pictured on the left and right respectively)

YOUR SEXUALITY

YOUR FACE GIVES away a lot – but not your political leaning. Researchers tested this in 2011 when they asked 19 subjects to look at the faces of 90 unfamiliar backbench male British MPs and to say whether they were from

the Labour or the Conservative party (using a rating scale to show how confident they were in their guesses). The results showed the participants were unable to judge the MPs' affiliations from their faces. MPs with beards or glasses were excluded in case these were used as cues.

Sexual orientation is another matter. Research from 2008 by Tufts University found that a 50 millisecond glimpse of 90 men's faces was enough for undergrad students to judge their sexuality (homosexual or heterosexual) with an accuracy of 57 per cent, which is superior to chance. "The rapid and accurate perception of male sexual orientation may be another symptom of a fast and efficient cognitive mechanism for perceiving the characteristics of others," the researchers say.

WHAT YOU EAT

10

IF SOMEONE HAS an orange glow, it's tempting to assume they've been spending too much time on a sunbed. In fact, a person's diet - specifically the consumption of carotenoid-rich fruit and veg such as carrots can also affect their skin in a similar way, making it appear more yellow. In 2014, psychologists from the University of Leeds and the University of St Andrews showed that faces made more yellow through diet were rated more attractive by observers than the same faces with an equivalent suntan. It's thought that skin turned yellow through diet is attractive because it's a sign the person is in good health.



High melanin

CHRISTIAN JARRETT is a psychologist and the author of Great Myths Of The Brain





LIFE AT ITS BEST

















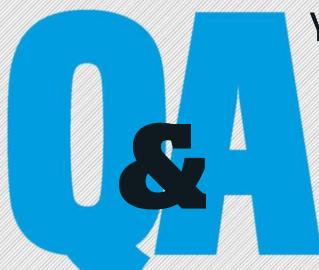


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YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEI



SUSAN BLACKMORE Susan is a visiting psychology professor at the University of Plymouth. Her books include *The*

Meme Machine



DR ALASTAIR
GUNN

Alastair is a
radio astronomer
at the Jodrell
Bank Centre for
Astrophysics at
the University of
Manchester



ROBERT **GARETH MATTHEWS** MITCHELL After studying Starting out physics at Oxford, as a broadcast engineer, Gareth Robert became a science writer. He's now writes and Visiting Professor presents Click on the BBC World in Science at Aston University Service

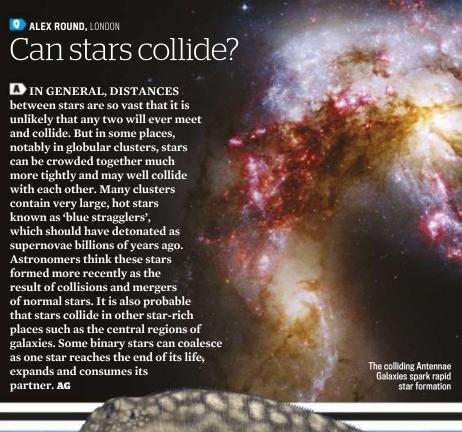


LUIS
VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include How Cows Reach The Ground

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com

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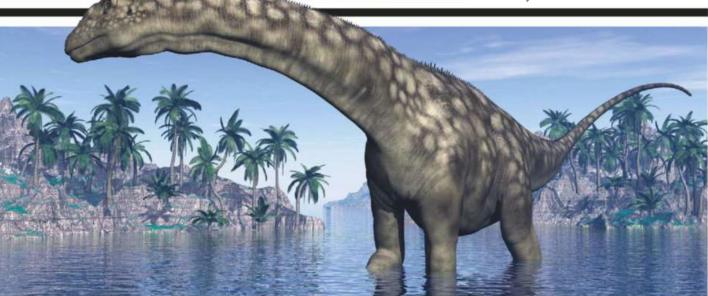


Whip it all you want, it will still

TOM MITCHELL. DURHAM

Why does Marmite go pale when it's stirred repeatedly?

MARMITE LOOKS DARK because any light entering it is likely to be absorbed by molecules of the stuff, and thus prevented from escaping again. Stirring it introduces air-filled cavities that increase the chances of the light avoiding absorption and managing to escape. Whipped Marmite can generate so many bubbles that it turns white. RM



LIAM FARMER, BIRMINGHAM

How big could an animal get?

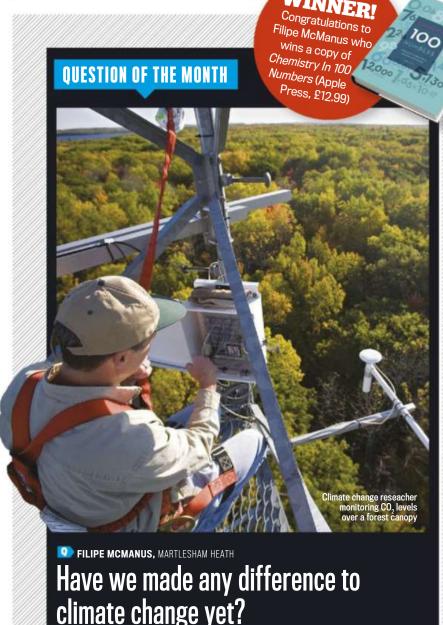
BASED PURELY ON the physical strength of bone and muscle, it has been calculated that land animals of at least 100 tonnes and possibly as much as 1,000 tonnes ought to be able to support their own weight and move around. That's much bigger than even the largest dinosaur (Argentinosaurus probably weighed 80

tonnes at most), but that's because other limits cut in first. The largest animal to have ever lived is the blue whale. At 180 tonnes, it already has to eat 1.5 million calories a day. Blue whales eat krill, which is one of the most abundant food sources in the ocean. Even so, about half the global population of krill is eaten every year by

the blue whale

Argentinosaurus, the biggest dinosaur, is still dwarfed by

whales, seals and fish. A single freak blue whale that was double the normal size could still probably find enough food to sustain itself. But if all blue whales grew this big, the population would need to be smaller and they would reproduce even more slowly than they do now, making them more vulnerable to extinction. LV



climate change yet?

A QUITE POSSIBLY – BUT not in a good way. The principal drivers of climate change are greenhouse gases that trap the Sun's heat. The most important of these is carbon dioxide (CO₂), produced by human activities such as energy generation and transportation. The good news is that 2014 saw CO, emissions from the energy sector remain static, suggesting the message about fossil fuels is finally getting through. The less good news is that in May the total amount of atmospheric

CO, exceeded the highest level recorded since scientific measurements began in 1958.

Perhaps most concerning of all is the fact that even if emissions of all greenhouse gases ceased entirely tomorrow, any warming would still persist for many centuries. That's partly because CO, lingers in the atmosphere for several centuries after release, and partly because the oceans are slow to respond to global warming but are also just as sluggish to react to any cooling. RM

SEONAID JOHNSTON, PERTH

Why don't we sneeze in our sleep?



Even if an insect crawled across your nose, you probably wouldn't sneeze while dreaming

DURING REM SLEEP (the phase where dreams take place), your muscles are paralysed so that you don't thrash around and hurt yourself. This paralysis extends to reflex muscle contractions, so you can't sneeze while you are dreaming. In non-REM sleep your muscles are free to move again but the trigeminal motor neurones responsible for triggering a sneeze are still suppressed. It is just about possible to sneeze during this non-REM sleep, but the exertion will normally wake you up. **LV**

HARVEY WOOD. BY EMAIL

Could we create a breathable atmosphere on Mars?

NARIOUS IDEAS HAVE been proposed, many involving the release of chemicals into Mars's atmosphere to trap the Sun's heat, triggering a greenhouse effect. This might then make Mars suitable for bacteria or plants capable of turning carbon dioxide into oxygen. So, it may be possible - but don't hold your breath. RM



TOP 10

STRONGEST ANIMAL BITES

AVERAGE HUMAN BITE IS 162PSI



1. Nile crocodile

Bite force: 5.000psi Distribution: Sub-Saharan



Saltwater crocodile

Bite force: 3.700psi Distribution: India, Southeast Asia, Australia



3. American alligator

Bite force: 2.125psi Distribution: Southern USA



Bite force: 1,800psi Distribution: Sub-Saharan



Bite force: 1,500psi Distribution: Southwestern USA, Central America, South America

6. Bull shark

Bite force: 1,350psi **Distribution:** Warm coastal areas, rivers and lakes worldwide

7. Gorilla

Bite force: 1,300psi **Distribution:** Forests of central Africa

8. Polar bear

Bite force: 1,200psi Distribution: Arctic Circle

9. Grizzly bear

Bite force: 1,160psi Distribution: Canada and USA

10. Hyena

Bite force: 1,100psi Distribution: Sub-Saharan FEDERICO TAK. OXFORDSHIRE

What caused the Big Bang?

THE BIG BANG is the

moment that space and time (or 'spacetime') came into existence. Before the Big Bang there was no space or time. So, it is actually meaningless to ask what caused the Big Bang to happen – there was no Universe in which that cause could have existed. This might seem like a bit of a cheat, but there are other good reasons to suppose a cause for the Big Bang might not exist. Quantum physics has shown us that some events have no cause at all. Things can happen randomly, spontaneously, and for no particular reason. This unpredictable and 'causeless' nature of the Universe is experimentally verified but has nothing to do with our inability to observe correctly – it is a fundamental property of the Universe. So, although there may have been a cause for the Big Bang that we are unaware of, modern cosmology neither defines nor requires one. AG

💔 Did you know?

The heaviest ever pumpkin weighed 1,054kg and was grown by Switzerland's Beni Meier in 2014



EMMA COOK, SLOUGH

Why do we cover our mouths when startled or shocked?

NOT TO PREVENT our souls leaving our bodies, as some traditions would have it. The gasp which causes our mouths to open when we are shocked is a fast, deep in-breath that evolved to provide a quick burst of extra oxygen to help deal with startling events. This makes the mouth vulnerable, so covering it may be a protective gesture. It is also a way of concealing our emotions from others, to avoid showing that we are afraid, shocked or disgusted. Many experts say that the response is learned as a form of politeness but, like many other gestures, this behaviour is seen across various different cultures. So the reaction may have some inherited basis, but in modern times it may often just be a way of hiding the fact that you were startled by nothing more serious than a fly, or shocked by what your friend said. SB



STEPHANIE WARD. HARROGATE

Can an organ be transplanted more than once?

YES. SOMETIMES PATIENTS will receive heart or liver transplants but die anyway within a few weeks. In very rare cases, the donated organ was still healthy enough to be worth re-transplanting to a new patient. In 2012, a 27-year old man from the US received a kidney transplant but then had it removed again two weeks later because the disease he was suffering from was damaging the kidney. Doctors rescued it in time and gave it to a 67-year old man instead, and returned the first patient to dialysis treatment. LV

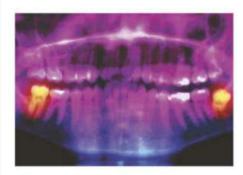


WHAT IS THIS?



REBECCA GILL. LEATHERHEAD

Why do we have wisdom teeth?



WE EVOLVED FROM hominids that had longer jaws for chewing raw meat and plants. Extra molars are an advantage, but they don't emerge until adulthood. This gives the jaw time to grow large enough to accommodate them. As teeth are widest at the top, spaces between them can also emerge as the molars start to wear down. The new teeth at the back encourage the remaining teeth to shuffle up and close the gaps. We don't need wisdom teeth any more, nor do we have enough room for them. But dentistry offers a quicker fix than evolution. LV

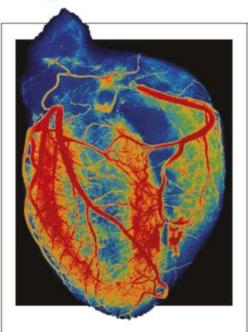
UD HUGH ALLEN. SOMERSET

How fast can a housefly fly?



NOT AS FAST as you think. They manage just 7km/hr – a brisk walking pace. They seem faster because they are very acrobatic and hard to catch. The fastest flying insects are dragonflies, with a top speed of 56km/hr (35mph). LV





TONY FERRER, HIGH WYCOMBE

Does a human heart have a finite number of beats?

YES. AT AN average of 80 beats per minute, most of us will manage less than four billion beats in our lives. But you don't die because you run out of heartbeats – you run out of heartbeats because you die.

Among mammals, the number of heartbeats over the lifespan of different species is fairly constant. So hamsters' hearts beat 400 times a minute and they live for about four years, which is 840 million beats, and an elephant manages 35bpm for 35 years, or about 640 million beats total. Those numbers are similar, but that's just because animals with faster heart rates are also smaller and more at risk from predation and starvation. Their lifespans have evolved to compensate for this by reproducing early and often they 'live fast, die young'. Heart muscle can only repair itself very slowly, so eventually every heart will wear out but not after a specific number of beats. LV

In Numbers

7,000

blood donations are taken in the UK every day, and one in four of us will need a tranfusion at some point in our lives LISA COOPER, BRIGHTON

When does the difference between mean and median matter?



⚠ WE ALL REMEMBER those boring maths lessons where the teacher droned on about the difference between the mean of a set of data, and the median. Yet the difference can be vital to understanding some controversial issues. For example, the latest official statistics show that men working full-time in the UK get paid on average around 17 per cent more than women. But that figure masks the impact of the relatively small proportion of men who get paid colossal amounts. Whenever data is seriously skewed like this, the median becomes far more representative of what's 'typical' than the mean, as it's the value which splits the data exactly in two, with 50 per cent being above the median and 50 per cent below. In the case of pay, taking the median shrinks the gender gap among those in full-time work by around one-third, but its effect on part-time pay statistics is even more dramatic. While the mean says that men working part-time get around 5 per cent more than women, the median figures reverses this, showing that men typically get paid 5 per cent *less* than female counterparts. RM



PATRICK SEYMOUR, LEICESTER

How long is a jiffy?

FOR PHYSICISTS, A jiffy is how long light takes to travel a distance of one femtometre, which is a millionth of a millionth of a millionth of a millionth end that there are about three hundred thousand billion billion jiffys in a second. A jiffy also has an electrical meaning. It is the length of a single cycle of alternating current. In the UK's 50Hz system, a jiffy is thus one-fiftieth of a second. **GM**



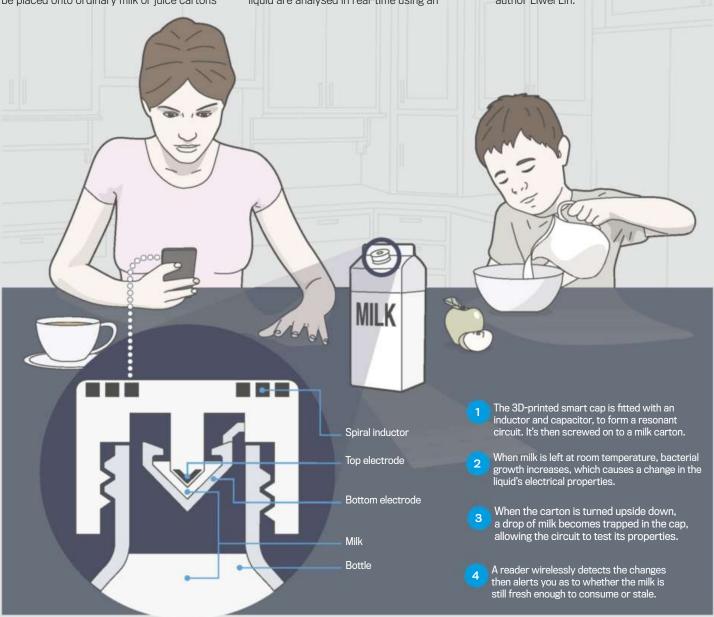
SMART CAP

RESEARCHERS AT THE University of California, Berkeley have designed a 3D-printed 'smart' bottle cap that lets you determine whether milk has turned sour – without needing to give it a sniff. This is the first time that working electronic components have been incorporated into a 3D-printed device. The specialised cap can be placed onto ordinary milk or juice cartons

to establish when a liquid has gone off. The main body of the cap is made from plastic polymers, with a conductive silver tube hidden inside. Electronics fitted to this tube turn it into a fully functioning circuit.

When a carton is quickly inverted, milk enters the circuit's capacitor, becoming trapped inside. Electrical signals in the liquid are analysed in real-time using an inductive reader, to measure the rate of bacterial growth.

In future, this technology could be embedded in a wide variety of packaging. "You could imagine a scenario where you can use your cellphone to check the freshness of food while it's still on the store shelves," says the study's senior author Liwei Lin.



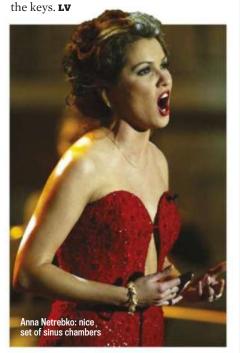
\$33.31

was the amount of money that astronaut Buzz Aldrin was reimbursed for his travel expenses on the Apollo 11 mission to the Moon back in 1969

MARGARET HUTT, AMERSHAM

What gives people a lovely singing voice?

THE GENERAL RANGE of sounds that can come out of your mouth is affected by the size of the vocal folds, the strength of your diaphragm and the shape of the chambers in your sinuses. But making this sound beautiful seems to be largely a question of training. At the basic level you must be able to hear a note in your head and reproduce it accurately with your voice. The difference between being able to hold a tune and having a genuinely beautiful singing voice is to do with the thousands of tiny and mostly unconscious muscle contractions that subtly adjust the resonant properties of your airway in response to the emotions you feel as you sing. This is the same with any musical instrument. Being born with a wide finger span helps when playing the piano, but the rest is learning the subtleties of timing and pressure on



MIKE DAWES, LIVERPOOL

What's the difference between a psychopath and a sociopath?



THE TWO CONDITIONS are often treated as the same, but psychiatrists identify important differences. Both disregard laws, customs and the rights of others and feel no guilt or remorse for their behaviour. Both can be violent, although not all are. Sociopaths, however, are also disorganised, impulsive and volatile and can rarely hold down a job. They

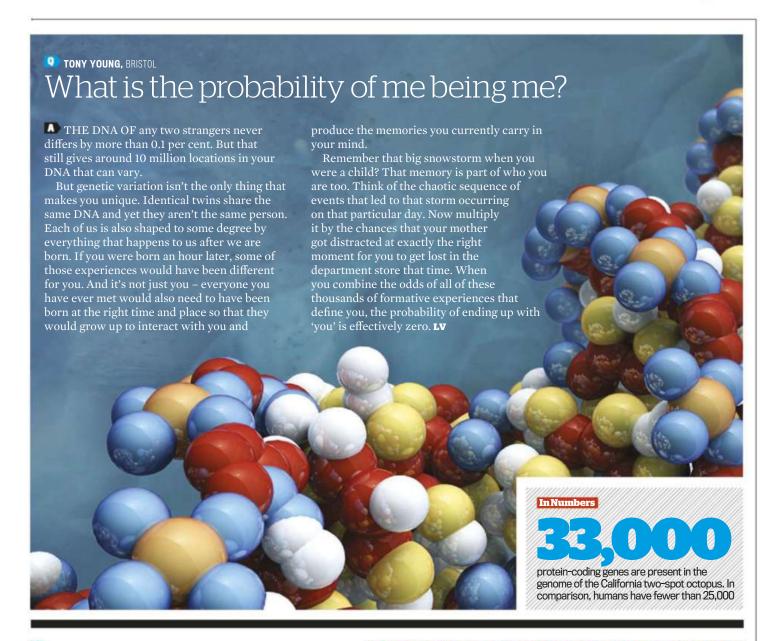
appear very disturbed and their crimes are usually spontaneous. By contrast, many psychopaths lead relatively normal lives, manipulating people and mimicking emotions they cannot feel themselves. Their crimes are usually meticulously planned. There is some evidence that psychopathy is inherited while sociopathy is due to childhood trauma or neglect. **SB**

RICHARD O'NEILL. GLASGOW

Does eating locally produced honey help alleviate hayfever?

NO. THE MYTH is that local pollen in honey can desensitise the allergic reaction, but there's no evidence to support it. A 2002 study at the University of Connecticut compared locally-produced, unfiltered honey, with nationally-produced, filtered honey and honey-flavoured corn syrup. In double-blind trials, there was no difference between the three in reducing hay fever symptoms. The pollen in honey is nearly all the heavy, flower pollen that doesn't cause hay fever. The pollen that sets your nose running is much lighter and comes from grasses and trees that bees don't visit. LV





JAMIE TODD, KENT

Why does spicy food taste hot?

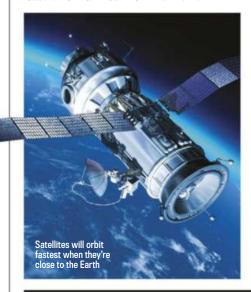
THE ACTIVE INGREDIENT in chilli peppers is capsaicin, one of several related compounds called capsaicinoids that bind to vanilloid receptors inside the mouth and on the tongue. These receptors detect heat and send a signal to the brain about temperature. So it is an accident of nature that capsaicin activates them, tricking the brain into responding to spicy food as though it were hot. You might think we ought to avoid such foods rather than enjoy them but they may serve many functions. Capsaicinoids are known to increase energy and reduce appetite; they also increase salivation, making it easier to eat bland food such as plain rice. Another theory is that the pain of hot chillies is a kind of benign masochism. The 'heat' reduces other pain by inducing the release of endorphins, which are the body's natural painkillers, and gives a sense of wellbeing. SB



HAFIZ MALGHANI. PAKISTAN

What determines the speed of an object orbiting our planet?

OBJECTS CAPTURED BY the Earth's gravitation typically have elliptical orbits. The mean orbital speed of the object depends only on the Earth's mass and the semi-major axis (half the longest diameter) of the object's orbit. However, the orbital speed changes depending on where in the orbit the object is. It will be greatest when closest to Earth and least when furthest from Earth. **AG**



RYAN COOKE, ST ALBANS

Is it really possible to control a robot with your mind?



YES IT IS. The USA's Defense Advanced Research Projects Agency (DARPA) has a brain-controlled prosthetic arm for upper limb amputees. As the user thinks about various movements, the arm picks up the responding brain signals that appear in the remaining nerves at the site of the amputation. With incredible dexterity, the user can remove a letter from an envelope and even move eggs from one box to another. But away from

government-funded research projects, hobbyist and engineer William (Chip) Audette in Vermont controls a small toy robot using his brainwaves. He's using open hardware called OpenBCI where electrodes on his head pick up brainwaves. The level of control is crude but is proof that advances in EEG technology, machine learning and robotics really are ushering in an age where we can control devices through the power of thought. **GM**



LUCIE COLTMAN. VIA TWITTER

Do people in a coma dream?

A PATIENTS IN A coma appear unconscious. They do not respond to touch, sound or pain, and cannot be awakened. Their brains often show no signs of the normal sleep-wakefulness cycle, which means they are unlikely to be dreaming. Yet many people who have recovered from comas report dreams into which something of the outside world penetrated. Others recall nightmares that seemed to go on and on. Whether they dream or not probably depends on the cause

of the coma. If the visual cortex is badly damaged, visual dreams will be lost; if the auditory cortex is destroyed, then they will be unable to hear dreamed voices. If the cause is damage to brain areas such as the reticular activating system, which controls the sleep-wakefulness cycle, normal dreams cannot occur but other dream-like states might. The term 'coma' covers many conditions. Until we understand them better, it is hard to say which ones can include dreams. SB

CHARLIE GREGSON, BY FMAIL

Why does helium change your voice?

■ SOUND TRAVELS FASTER through a lighter gas than a heavier one. This is because the individual gas molecules have less mass and can therefore move more quickly in response to the pressure changes of the sound wave. The speed of sound in helium is almost three times

the resonant frequency of your throat so that high frequencies sound louder than low ones. If you inhale a gas that is denser than air, such as sulphur just 39 per cent of its speed in air and your voice sounds deeper. LV

faster than in air. This changes hexafluoride, the sound travels at



facial expressions have been recorded in horses by scientists at the University of Sussex. Dogs manage 16, while we have 27

LISA PRICE. TEWKESBURY

Is arachnophobia learned or an instinct?

BOTH. OVERALL RATES of arachnophobia are around 5 per cent, although a milder fear of spiders is reported in up to one-third of the population. More women than men fear the arachnids, even in countries that have no dangerous spiders. Arachnophobes may scream or have panic attacks on seeing a spider, and judge spiders as bigger and closer than they are, so increasing their fear. There are good reasons why arachnophobia might be inherited. We evolved over millions of years in Africa. Here, many spiders are venomous and avoiding them could be useful. But this does not prove the case, and excessive fear might even be counter-productive. Children tend to fear spiders if their parents do, but this need not be genetic. Like many mammals, we learn preferences and fears from our parents at a young age. Watching a parent react with terror to a spider in the bath could instil fear in the child. So this makes it hard to know how much of this fear is learnt or inherited. SB



NEXT MONTH Over 20 more of your questions answered



For even more answers to the most puzzling questions, see the Q&A archive at www.sciencefocus.com/ganda

JANE FRANKLIN. VIA FMAIL

Can we find where MH370 crashed, now that wreckage has washed up?

BY EXAMINING THE TIDES and currents of the Indian Ocean, it is possible to identify the general whereabouts the MH370 plane, but its exact location may remain a mystery.

Mapping the route by which the wreckage must have reached the island of Reunion (pictured), researchers have concluded that the plane hit waters off the west coast of Australia. Australian authorities are therefore searching these waters, spanning the investigation across 60,000km2 of sea.

Furthermore, the washed-up wing debris is currently being examined for

additional clues, using the multitude of barnacles and microorganisms attached to its surface. These can be analysed to determine which part of the sea the plane landed in, as well as the time taken for the wreckage to reach Reunion. By applying this time to the routes of ocean currents and gyres, it may be possible to build a more accurate picture of where the debris came from. Focus



Why do toothpaste and orange juice taste so horrible together?



A THE TASTE BUDS ON your tongue are covered in proteins that act as receptors for food particles. When in contact with food and drink, these receptors send a message to your brain, evoking one of the five taste sensations: sweetness, sourness, saltiness, bitterness, or umami.

When you brush your teeth, the toothpaste releases a foaming agent called sodium lauryl sulphate

(SLS). This SLS interferes with the proteins that line the membranes of taste cells in the mouth. This impairs the tongue's ability to taste sweet flavours, replacing them with an unpleasant, bitter sensation. The SLS also destroys bitternesssuppressing phospholipids, allowing the bitter taste to take over, resulting in the unique and horrible flavour you experience when you sip orange juice. Focus

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The Network Innovation

THE FUTURE OF GADGETS THIS MONTH 🕙 **APPLIANCES OF SCIENCE** A retro synth, a rolling robot, a smart action camera, and more! **ULTIMATE TEST** Hybrid cars you will hunger for p90 SEARCH How are you feeling?... ICK OF WAITING so Recently, it launched an app diagnosed by artificial long to see a doctor

ON THE HORIZON

Digital diagnoses are coming to a desktop near you usa.baidu.com

before you find out what's wrong with you? Well, now there's a solution – for patients in China, at least. Baidu is a Chinese web services company that operates Chinese-language

that you get better

equivalents of Google and Wikipedia, but it also runs research projects in both Beijing and Silicon Valley.

that can diagnose patients' medical problems and put them in touch with a local GP.

But what makes Baidu's AskADoctor software different to the existing contact-a-GP websites and apps, such as ask-a-doctor.co.uk (a separate enterprise to Baidu's new scheme) or onlinedoctor. lloydspharmacy.com, is that there's no medical practitioner at the other end of the line. Instead, your condition is

intelligence (AI). And it's an AI with voice-recognition capability, which means patients don't have to painstakingly type their symptoms out or select them from a series of checklists.

Baidu's researchers have built a system that can deal with spoken Mandarin - no easy feat considering that it's a tonal language - but can also cross-reference what it hears with the vast health



Baidu is a web services company in China that is looking to make headway in the world of artificial intelligence

records that the company has on file to arrive at a suitable diagnosis. It's said the system can identify over 500 different diseases, which comprise 90 per cent of the most common medical problems in China.

Once a diagnosis has been reached, the system will put the patient in touch with a local doctor who can confirm the result and prescribe the relevant treatment. While Baidu's AskADoctor is currently a desktop app, work is already underway on creating a smartphone and tablet version for health help on the go. It's hoped the software will help to ease the pressure on China's stretched healthcare system.

AskADoctor is the one of the first creations to come out of Baidu's 'deep learning' branch. In this research area, computers are programmed to behave like brains and infer things through recognising patterns. The man heading up Baidu's work on artificial intelligence is Chief Scientist Andrew Ng, who is a Stanford professor and one of the specialists who worked on the Google Brain before being hired by the Chinese company in 2014.

Developing a deep-learning system relies upon building a neural network of computers and providing it with a vast amount of data to process. In doing so, the

network 'learns' to spot particular groupings within the data and can draw conclusions when those groupings appear. For example, the Google Brain learnt to recognise cat videos after being exposed to a selection of 10 million random YouTube clips. But in the case of Baidu's AskADoctor, speech and symptoms are being used to identify particular medical conditions.

Baidu hopes that the AskADoctor app is the first step in a journey that will eventually lead to a medical robot. But Baidu is a commercial enterprise and ultimately needs to make a profit to survive. AskADoctor may not be staffed with GPs that have to be paid, but like existing online medical services it does charge patients for putting them in touch with a local medical practitioner (ask-a-doctor.co.uk offers a free sevenday trial, after which it starts charging a subscription fee of £20-per-month).

Could Baidu's system be the key to delivering David Cameron's election promise of seven-day access to a GP? Perhaps, but if you can't pay for it will you be left loitering in the waiting room?

ROB BANINO is a freelance science, health and technology journalist

TECHOMETER

WHAT'S HOT

HA HA AND 🗯



WHAT'S NOT

LOL

abbreviating text-speak abbreviation for 'laughing out loud' has fallen out of favour, if Facebook's survey is anything to go by. LOL appeared in just 1.9 per cent of posts on the social network during the last week of May 2015. The world hasn't stopped wasting time at work by sharing clips of cats falling over or wearing silly hats but, according to Facebook, we're acknowledging them in ways that are less annoying.

READER POLL

Would you trust an Al doctor?

No - I'd prefer to wait for a proper GP appointment 17% Yes - I'd trust them with my medical details

THE NEXT BIG THING

BETTER BATTERIES

Tapping into the biggest power source in the Solar System

N HIS REMARKABLE science-fiction novels about an advanced civilisation called the Culture, Iain M Banks solves the problem of fuelling a starship by using limitless energy from The Grid, a fictional field between our Universe and a mirroring antimatter one. It's a nice idea but in the real world we have to make do with more traditional methods of generating and distributing power.

As many have pointed out, there's more than enough energy arriving from the Sun every second to fuel our needs but capturing it in a useful form is a challenge. Currently we rely on a million-year-long process of compressing organic remains into coal and oil to make fuel, a method that's both inefficient and causes unwelcome climate changes.

But we are on the verge of a transformation in our relationship with energy partly because of the increasing efficiency with which we can convert light into electricity but also due to developments in battery technology.

Electric-car maker Tesla got a lot of attention this year with the launch of its 'Powerwall'

battery systems, offering an alternative to the existing electricity grid. At the Intersolar conference in June. Tesla's JB Straubel argued that falling battery costs and improvements in solar panels mean we'll soon be able to generate, store and deliver electricity more cheaply than with current fossil fuel systems.

But we won't do this with existing battery technology. The main reason is that conventional batteries are just too complicated and bulky. A lithium-ion battery like the one in your laptop isn't just a collection of chemicals but a complex machine with built-in safety systems to contain the highly reactive chemicals that store the energy.

A promising direction for battery technology seems to lie in solid-state devices such as the Sakti3 battery, which has been getting some publicity thanks to a \$15m (£9.5m) investment by the domestic appliance manufacturer Dyson.

This doesn't mean that incremental improvements in Li-ion technology won't matter, or that we won't be using lithium-based batteries for many years. The basic physics of batteries is still being



Improvements in batteries and solar technology would make our cities greener

uncovered and turning a promising discovery in the lab into something that can be manufactured and shipped to consumers is a long, complex and error-prone process.

But just as flat-screen technology replaced the bulky cathode-ray tube monitors of the last century, once we see a reliable solid-state battery I think it will replace today's best efforts relatively quickly and provide the basis for the

zero-carbon energy systems that we so desperately need if we are to avoid the worst consequences of two centuries of profligate use of fossil fuels. It's either that or we find a way to tap into The Grid.



THOMPSON contributes to news.bbc.co.uk and the BBC World Service

THE LAB PLASMA ACTUATORS

WHAT ARE THEY?

These devices use an electric current to control air as it passes over a surface in other words, a way to improve a vehicle's aerodynamics.

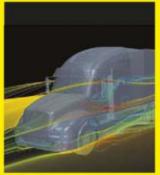
WHY ARE THEY IMPORTANT?

Due to its shape, a truck is about as aerodynamic as a brick so a lot of energy goes into pushing the air out of its path.

Shaped body panels, spoilers on the roof of the cab and tails for the trailers can improve a truck's aerodynamics - and in doing so increase its fuel efficiency and reduce its running costs - but they add weight and can make it difficult to maintain the vehicle and load/unload its cargo. Plasma actuators can do the same job without adding extra weight or inhibiting the truck's use.

HOW DO THEY WORK?

The actuators (made out of a pair of asymmetrical electrodes) are built into the truck's bodywork. When a current is passed between them a layer of plasma is formed that can be used to adjust the direction and speed of the air flowing over it and lower the wind resistance. They also glow, so trucks driving at night would give off an eerie purple light.



Keep on truckin': Plasma actuators could have haulage applications

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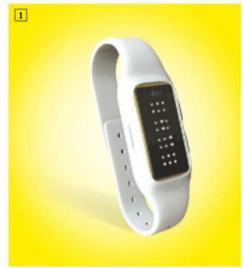
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APPLIANCES OF SCIENCE

BRAILLE BUDDY

This might look like yet another fitness tracker, but it's actually a Braille smartwatch. As well as doing all the usual smartwatch stuff, Dot can also function as an e-book reader, and there's a built-in Braille tutor for those who can't already read it. Surprisingly, that's actually the majority of the blind population meaning that Dot could transform lives in a way that an Android or Apple watch never could.

Dot

\$300 (£190 approx), fingerson.strikingly.com

JAZZY ODYSSEY

The ARP Odyssey duophonic synth was released in 1972 and graced recordings by everyone from ABBA to Deep Purple. It was discontinued in 1981, and secondhand machines have traded hands for increasing sums ever since. But now Korg has rebooted the Odyssey, adding USB and MIDI connectivity, and XLR outputs, as well as incorporating the three filters from all three original Odyssey models.

ARP Odyssey £899, arpsynth.com

COMPACT 'COPTER

Small enough to fit in the palm of your hand, this tiny quadcopter is nonetheless equipped with LED lights and an high-definition (1,280x720-pixel) camera that shoots video footage and stores it on a microSD card. With a choice of Beginner and Advanced flying modes, four motors and six-axis auto-stabilisation, you'll be pulling off barrel rolls and figure-eights in no time.

Skeye Mini Drone \$99 (£65 approx), trndlabs.com

SPARK YOUR IMAGINATION

Focus readers will surely be familiar with Nikola Tesla and his coil - a transformer circuit used to generate AC currents. Now you can build your very own miniature, USBconnected coil and use it to make music by varying the voltage. The TinyTesla kit comes with full instructions and all the components you need, and would make the perfect inspirational gift for budding engineers.

TinyTesla \$229.99 (£147 approx), onetesla.com

ROLLING ROBOT

Meet Sphero SPRK, a programmable robot that whizzes around at 4.5mph and has been designed to help youngsters learn coding skills. Based on the existing Sphero 2.0 but now housed in a clear shell, Sphero SPRK comes with an iOS/ Android app to program the robot's movements. Various apps for the Sphero are also available, as well as skatepark-like ramps and obstacles.

Sphero SPRK \$129.99 (£85 approx), sphero.com

MOVIE MAGIC

This camera takes the tedium out of editing footage - by doing it for you. Equipped with a gyroscope and accelerometer, it can also be linked up to a heart rate monitor. By combining this data with the audiovisual info, it identifies the best parts of what you've filmed - so you can shoot all day, then ask Graava for a highlights reel. It'll even sync your footage to your fave music.

Graava \$399 (£260 approx), getgraava.com



HYBRIDTAKEOVERS

With sales of 'alternatively fuelled vehicles' on the rise, Daniel Bennett tests two of the best to find out if it's worth switching over... GVI4 JJZ



It was hailed as a game-changer.

But the Prius wasn't the first hybrid car. In fact, the idea had first emerged in 1900 when Ferdinand Porsche - the man who developed the VW Beetle and founded Porsche - brought the Lohner-Porsche Elektromobil to the Paris Exposition. The initial concept car was powered by a battery, but Porsche would later add an engine that would recharge the batteries.

The idea of a hybrid would re-emerge in the 1920s, 70s and 80s, but it was

But as the offered mpg of hybrids soared, they became harder to ignore.

Today, over half of the eight million hybrids worldwide are a Prius, but there's more to the technology than this one car. Hybrid drivetrains are on the rise, and next year almost every manufacturer will have its own hybrid car. So we tested two of the most popular models that offer alternatives in key markets - SUV and executive cars - to see if it's time to switch...



the exhaust - less than a new Ford Fiesta.

On our first stint with the car - driving up the M4 from Bristol to London - the Outlander managed around 50mpg but once we were in the capital, darting in and around the traffic, it averaged 60-70mpg. Against the claimed figures these numbers seem a tad disappointing, but for the car's size, they're still pretty laudable. Then factor in that we didn't have to pay congestion charge or road tax, and would have paid £5,000 under the ticket price thanks to the Government's plug-in car grant, and it's hard to find a new car that offers as much at this price.

The electric motor doesn't just make the car economical, either. The instant jolt of power from the battery means 0-20mph is nippy for a car this size. In fact, you could just run the car on the batteries' 32-mile range (though in practice you may get less than that) and plug it into a special port or your home supply to top up. For many that'd handle most journeys comfortably, while the petrol engine gives you the option to go further at the weekend. There's also the option to use the car's own engine to charge the battery - though we can't work out exactly why that's of use.

The Outlander PHEV ticks a lot of boxes if you're looking for a family car: it's frugal, eco-friendly, spacious and rugged. I was sceptical at first, but once you use the car it seems eminently sensible to have an SUV that you can run cheaply during the week, and then stuff full at the weekend before driving out into the countryside.

Our only grumbles were with the frustrating infotainment system and the workmanlike interior, but for many buyers those things simply won't matter. Besides, this is the first iteration of a car that proves how versatile a hybrid can really be. It can only get better from here.

From £28,249, mitsubishi-cars.co.uk



IF YOU DON'T fancy the fish-out-of-water styling of the Prius, then the Lexus IS 300h could be a step-up worth considering. While its luxury competitors, like BMW and Mercedes, have focused on diesel cars to provide better economy, Lexus – owned by Toyota – has concentrated on hybrid drivetrains.

Once you slide inside the Lexus, this makes perfect sense. Thanks to its electric motor, it pulls away from the lights in complete silence. Even when the petrol engine does kick in, it's barely audible. And silence, of course, is exactly what you want your luxury car to sound of! Together the two motors offer a claimed 60mpg – we only managed 40–50mpg on average, though we could probably have used a lighter foot. The trouble is that the IS 300h is such an enjoyable car to drive, you forget that it's supposed to be green. On the motorways it eats up the miles, delivering you to the other end just as rested as you were when you got in.

The seats are remarkably comfortable, the ride is supple and the driving position is perfect. You're low to the ground so you feel connected to the road, while still being able to see all four corners of the car easily.

Throughout the interior, there are small features that make the car feel special, like small panels of brushed aluminium or touch-sensitive strips which you slide your finger across to adjust the air con. Even the audio system - thanks in part to the quiet cabin - feels precise.

Unfortunately, the IS 300h does suffer from one major weakness. For such a smartly presented car, its infotainment system feels decidedly old-fashioned. The small input joystick is overly sensitive, skipping over your selections, and the menus are often frustrating. It's a weakness that's perhaps amplified by the overall quality of the rest of the car.

Despite this, the IS 300h is the first hybrid - well, outside of a BMW i8 - that we'd actually want to own, and it proves that there are more benefits to hybrids than simply how much carbon they produce and how much money they can save you.

From £28,995, lexus.co.uk

DANIEL BENNETT is acting editor of Focus

THE FUNCTION OF HORMONES

BY TOM IRELAND

These clever chemicals circulate through our blood, regulating our physiology and behaviour. But it took a long time for people to accept that these molecules have such an enormous impact on our bodies

ODAY, THE WORD
'hormone' is commonly
used and well understood.
We might say we are feeling
hormonal, or take hormones
to prevent, say, diabetes
or pregnancy. Teenagers,
especially, are known for
being troubled by their
'raging' hormones.

These amazing chemicals, secreted into our blood by special organs called endocrine glands, control almost everything our body does – from our growth and development to our impulses and mood, from how often we sleep to how quickly our heart beats. There are even hormones that regulate our hormones.

Yet until the start of the 20th Century, most scientists had no idea hormones even existed, let alone how they worked. The more visible systems of the body, such as the skeleton, muscles and major organs, had been known since ancient times. However, hormone glands were only just being found by anatomists by the 19th Century, and what they did remained a complete mystery for some time.

Despite this complete lack of understanding, humans have been

unwittingly manipulating hormones in both animals and people for centuries. There is some evidence that ancient Chinese people were extracting hormones from urine for medicinal purposes as far back as 200BC. In Italy from the 16th to the 18th Centuries, opera singers known as castratos had their testicles removed before puberty to ensure their voices didn't drop, producing a unique high-pitched voice in adulthood. And for thousands of



Domenico Annibali was castrated as a youngster and became an international opera star in the 18th Century

years, farmers have castrated male animals to reduce aggression.

WEIRD SCIENCE

But it took a series of crude and controversial experiments in the Victorian era to kick-start the discovery of hormones and our understanding of how they actually work. Many of them still involved doing strange things with testicles.

Over the course of around 100 years, the new field of 'endocrinology' – as the study of hormones is called – revolutionised science and medicine, and many common disorders of the endocrine system could suddenly be diagnosed and treated.

The story begins in 1849, with a German scientist called Arnold Berthold and several castrated cockerels. Berthold noticed that when cockerels had their testes removed early in life, in adulthood they failed to develop typically male characteristics, such as a large red comb and wattle.

In what is now recognised as the first endocrinological experiment, Berthold transplanted severed testes back into the birds' bodies. The birds soon started to develop the



traits of uncastrated cockerels, including the characteristic plumage and aggressive mating behaviour. The transplanted testes also redeveloped their own blood supply. The experiment suggested that whatever was causing the male characteristics was being emitted from the testes and into the bloodstream.

Despite the significance of Berthold's findings, his results went largely unnoticed at the time - it would be another half a century before scientists returned to his work and progressed his ideas. Other scientists theorised that 'internal secretions' might be affecting the function of

various organs, but the scientific community just couldn't comprehend that chemicals in the blood could have such wide-ranging effects on the body.

Towards the end of the 19th Century, the study of these mysterious glands and their functions went somewhat off-piste. A respected physiologist called Charles-Édouard Brown-Séquard began a series of outlandish experiments, most of which involved injecting himself with liquid squeezed out of crushed animal testicles. In 1889, at the age of 72, he announced that he had reversed his own ageing by injecting the 'testicular juice' of dogs and guinea pigs.

The effects Brown-Séquard experienced were almost certainly placebo. His injections would have contained little testosterone and would have been quickly broken down by his body. Yet Brown-Séquard went on to claim that almost any ailment could be cured by testicular juice. The news of his story led to a bizarre fad for such injections, and by the end of 1889 thousands of physicians were administering them, while chemists began selling 'miracle cures' made from various animal fluids.

Fortunately, as more robust experiments with glandular extracts continued, endocrinology soon

EXPERIMENT

Ernest Starling and William Bayliss wanted to prove that hormones regulate the function of organs. While controversial, their experiments set endocrinology on the right path

IN 1902 ERNEST Starling and William Bayliss were studying the nervous system's control of digestion at University College London. They were looking in particular at the duodenum - the part of the small intestine located immediately after the stomach. When gastric acid enters the duodenum, the pancreas releases pancreatic juice.

At the time, hormones were barely understood. A large number of scientists still thought that vital organ functions, such as the release of pancreatic juice, were controlled by the nervous system. To test this, Starling and Bayliss cut away all of the nerves in the pancreas and the duodenum of an anaesthetised dog. They found that pancreatic juice was still produced when acid passed through the duodenum.

They suspected that the duodenum was producing something that was entering the bloodstream and acting on the pancreas. To prove it, they scraped some tissue out of the duodenum, added acid, ground it up with sand, then filtered the mixture and then injected it into the dog's blood. The dog's pancreas began to produce pancreatic juice almost immediately. Since there was a chance they did not dissect all of the nerves in the pancreas and duodenum, this second experiment proved it was an agent in the blood that stimulated the production of pancreatic juice, not nerves.

The pair called the substance released by the duodenum 'secretin' and later went on to find it in all vertebrates.



Ernest Starling depicted during his experiment on pancreas function that led to the discovery of the hormone secretin

got back on track. In 1891, George Redmayne Murray announced he had managed to cure the medical condition myxedema. Now recognised as untreated underactivity of the thyroid gland, the condition caused alarming swelling of the hands and eyes.

Murray's treatment involved injecting extracts from the thyroid glands of sheep. Like Brown-Séquard, he simply chopped up the animals' tissues and squeezed the juice out, straining the murky fluid through a muslin sheet before injecting it straight into his patients. Unlike Brown-Séquard's potions, Murray's extract did contain high levels of thyroid hormones.

It would be many years before the thyroid's role in regulating metabolism and growth was understood, yet the treatment worked - making it the first effective application of endocrinology in conventional medicine.

By 1895 George Oliver and Edward Albert Schäfer had shown that injecting extracts of the adrenal glands and pituitary glands into animals raised their blood pressure. It was further proof that secretions released by glands could create important effects elsewhere in the body.

DARK PATHS

Despite mounting evidence of an internal chemical control system, the British Medical Association was still reluctant to accept the idea. The prevailing wisdom since ancient times was that the nervous system controlled the body's functions, and it was difficult for people to accept that this might not be the case.

This incomplete understanding led endocrinology down dark paths. In the early 1900s, thousands of men (including the poet WB Yeats) had a vasectomy-like procedure known as 'the Steinach' after the Austrian physiologist Eugen Steinach, who said tying off the testicles could reduce ageing and increase sexual vigour.

Tragically, from the late 1800s to the early 1900s, hundreds of thousands of healthy women had their ovaries removed - often by force - in the mistaken belief that it could prevent moodiness, hysteria, insanity and other conditions in later life.

To move on from these barbaric and crude ideas required a more thoughtful approach than the 'mash up a gland and see' method.

CAST OF Five innovative scientsts who hele characters understand how hormones work

Five innovative scientsts who helped us



Charles-Édouard Brown-Séquard (1817-1894) Brown-Séquard was a distinguished scientist from Mauritius who made many great contributions to medicine and our understanding of the nervous system. However, he derailed hormone science by injecting himself with the juice of animals' testicles and making

wild claims about how

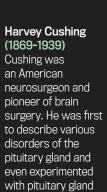
it made him feel.



Arnold Berthold (1803-1861) Berthold was a German physiologist and zoologist. He studied the organs and sexual characteristics of various animals, but it is his work on castrated cockerels that is remembered as the first experiment in the field of endocrinology.



Ernest Starling (1866-1927)Starling was the English physiologist who coined the term 'hormone' in 1905. Along with his brother-in-law William Bayliss, he made a number of contributions to the study of hormones. Their experiment to extract secretin is a classic.



transplants.



Rosalyn Yalow (1921-2011) was an American physicist awarded the Nobel Prize in 1977 for the development of the 'radioimmunoassay' technique. It measured minute amounts of hormones in blood or tissue samples. Although the tool revolutionised all areas of biochemistry, Yalow refused to patent the technique.



Thankfully, in 1902, a defining experiment was conducted by the physiologist Ernest Starling and his brother-in-law William Bayliss. The two were known to be compulsive experimenters, and they proved that chemicals in the blood could change how an organ behaves independently of the nervous system.

Having become known for this work, Starling was invited to give a series of lectures to the Royal College of Physicians in 1905. Here, while describing the chemical agents he and his peers had been studying, he used a word he had apparently made up the night before while dining with a scholar of Greek poetry. That word was 'hormone', based on the ancient Greek word for 'I arouse', or 'I excite', and the term stuck.

From here, advancement in endocrinology began to gather pace. In 1921 Frederick Banting and Charles Best discovered insulin, the hormone that tells the body to absorb sugar from the bloodstream. The pair's elegant experiment would lead to a treatment that still saves millions of lives.

Before Banting and Best's discovery, those with diabetes often succumbed to a slow and painful death at a young age. Type 1 diabetics do not produce enough insulin, meaning the sugar from the food they consume remains in their blood instead of being absorbed into their tissues for energy.

The pair started by removing the pancreas of a dog. The dog quickly became diabetic, indicating that the pancreas had a key role in the disease.

The majority of tissue in the pancreas secretes digestive juices, but the pair believed the organ had another function. In another dog, they tied up the pancreatic duct with string, causing the digestive juice-producing cells of the pancreas to wither and die. Ingeniously, what it left them with was just the cells of the pancreas they wanted to experiment on; these are now known as pancreatic islets.

After extracting the secretions from just these cells, they injected it into the diabetic dogs. Their blood sugar levels quickly returned to normal levels.

DRUG DISCOVERY

A year later, after working out how to purify their mixture, they injected their first human patient. Soon, they were personally injecting entire wards of diabetic children, who quickly

NEED TO KNOW

understanding endocrinology

ADRENALINE

Adrenaline is one of the most familiar hormones and is famed for the 'buzz' it gives when released during frightening or exciting moments.

) ENDOCRINE SYSTEM

Humans have at least 80 known hormones and 10 hormone-producing glands. The release of hormones, their effects, and their interaction with each other is known as the endocrine system.

THOMEOSTASIS

→ Hormones play a key role in the body's constant maintenance of a stable internal environment, known as homeostasis.

..........

HORMONE

HORMONE
Hormones are chemicals released by the body to control processes including digestion, metabolism, respiration, sleep, reproduction, mood and growth, to name a few. They travel through the blood and bind to specific receptors on the target cell, triggering a change in cell function.

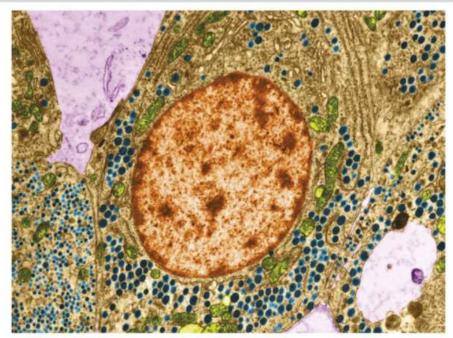
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T HPA AXIS

This stands for the hypothalamicpituitary-adrenal axis, a complex system including the hypothalamus, the adrenal and pituitary glands, and many hormones.

roused from their deathly stupor to the amazement of their families. Within two years of Banting and Best's discovery, a pharmaceutical company called Eli Lilly was making enough insulin, produced from animals such as oxen, to treat all the diabetics in North America. By the 1960s, the hormone was being created synthetically without the need for animals.

Modern endocrinology was now in full swing, and there were many major breakthroughs throughout the rest of the century. Many of them came thanks to the ability to measure minute quantities of hormones circulating in the blood. Such precise measurements would be impossible without a technique called the



Seen through the gaze of a transmission electron micrograph, a colour-enchanced cell (orange) in the pituitary gland can be seen secreting hormones (light green)

'radioimmunoassay', developed by an American physicist Rosalyn Yalow.

Yalow was awarded the Nobel Prize in 1977 alongside the endocrinologists Roger Guillemin and Andrew Schally. Her technique, which uses specially designed antibodies to bind to biological molecules of interest, allowed Guillemin and Schally to measure minute concentrations of pituitary hormones in the blood.

The work was vital in understanding the pituitary gland's role as a regulator of other hormone glands. Sometimes known as 'the master gland', the pituitary links the brain's hypothalamus region with the rest of the endocrine system. It is a crucial connection between the outside world, our senses, and the body's chemical response system.

According to endocrinologist and author Dr Saffron Whitehead. Yalow's radioimmunoassay and the development of high-resolution imaging are what have driven almost all of the advances in modern endocrinology over the last 50 years.

"The ability to do immunoassays has revolutionised endocrine research and diagnostics. For the first time levels of circulating hormones could be accurately measured," she says.

Today, our understanding of hormones has grown immensely scientists have discovered around 80 human hormones to date, and we now know that more tissues than

just the endocrine glands produce hormones. Work is ongoing to unravel the complex relationships between hormones and the great problems of our era like obesity, cardiovascular disease, depression, and ageing. Understanding the link between our genetics and our hormonal system will also keep endocrinologists busy for vears to come.

Whitehead believes there are still many more hormones to be discovered. "I think we will find that as well as being secreted into the bloodstream, there are hormones that act locally, between cells."

Today, endocrinology is at the cutting edge of the life sciences using modern lab techniques and computer modelling to understand the immensely complex biochemical systems that keep us alive. But modern science owes much to the physicians from the Victorian era, who first conducted those early and gloriously grisly experiments. ■

TOM IRELAND is managing editor of The Biologist, the Society of Biology's magazine

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Hour episode about hormones, visit bbc.in/1v22sB0

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PLAN YOUR MONTH AHEAD WITH OUR EXPERT GUIDE

PICK OF THE MONTH



WE'RE SURROUNDED BY colour every day, but how often do we actually stop to appreciate it? In this new three-part series, Helen Czerski takes a scientific look at the world of colour, revealing what it is, what it does and what it can tell us about the Universe we live in.

The first episode reveals how planet Earth became painted with colour. Take the deep, vibrant blue of lapis lazuli, a semi-precious stone that was forged by geological processes in the belly of our planet. Renaissance artists loved the colour so much that they ground it into ultramarine and used it in their masterpieces to paint the Virgin Mary's robes. "Every time you look at one of those paintings, you're looking at something that came out of the middle of a volcano," says Helen.

Episode two is all about the colours of life. The natural world is awash with colour, from the candyfloss pink of a flamingo to the succulent orange of an apricot. In fact, if you want a healthy glow, you might want to replenish your fruit bowl. "Carotenoids are the red and yellow pigments that make fruit and vegetables brightly coloured," says Helen. "They actually give your face a yellowish colour, and

research has shown that people with this colour are rated as healthier and more attractive."

In the final episode, we go beyond the rainbow. We usually see the world through a very small window of the electromagnetic spectrum but, as Helen shows, we're beginning to take advantage of the 'invisible colours' offered by ultraviolet and infrared light. "I got to fly on SOFIA, which is a completely bonkers aircraft owned by NASA," she says. "It's a modified Boeing 747 that looks like it's about to lay an egg." That egg is, in fact, an infrared telescope. The plane is flown 14km up into the stratosphere, where there's less water vapour to absorb the infrared light from distant celestial objects, enabling astronomers to study things like planetary atmospheres and colliding stars.

Colour: The Spectrum Of Science is set to be a feast for the eyes and the mind. Colour us excited!

JAMES LLOYD



Colour: The Spectrum Of Science airs on BBC Four this autumn. See **bbc.co.uk/colour** for details

DON'T MISS!



Building Cars Live

Learn how modern car plants work in this BBC Two documentary. p103



Why Music?

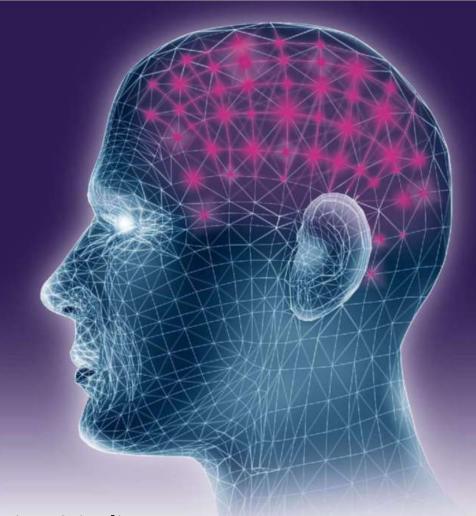
Explore the neurological effects – and therapeutic benefits – of rhythm and melody at this Wellcome Collection weekend. p105



The Evolution Of Everything

This new book argues the world is the way it is not because of human actions, but in spite of them. p106

Feed your mind



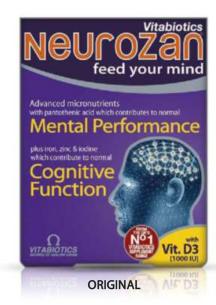
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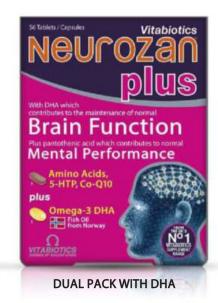
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20 SEPTEMBE

Dawn

Discovery, 7pm



Morning has broken!

MOST OF US know somebody who perkily insists that 6am is the best time of the day. Here's your chance to try out that theory, while still enjoying a lazy lie-in. *Dawn* explores the natural world during daybreak, filming a selection of bleary-eyed animals as they wake up in five beautiful locations – Zambia, Brazil, Mexico, Norway and Columbia.

an CENTEMBE

Warlords Of Ivory

National Geographic, 8pm



A park ranger with poached tusks

BRYAN CHRISTY IS the real-life Indiana Jones. Named National Geographic's Explorer of the Year in 2014, he's spent the past decade uncovering wildlife traffickers. In this programme, he conceals a GPS tracker inside a faux ivory elephant tusk, and, before he knows it, he's hunting down poachers in the heart of Africa.

26 SEPTEMBER

Inside The Mega Twister

National Geographic, 8pm



Rural Oklahoma after the twister

BACK IN MAY 2013, a monster tornado swept through rural Oklahoma, killing eight people and reaching ferocious wind speeds of up to 483km/h (300mph). This intriguing film tells the story of "the most dangerous tornado in storm observing history", using amateur footage, radar data and CGI animations to explain why this twister was so lethal.

JAMES LLOYD is the editorial assistant at BBC Focus Magazine



It still looks better than our first car

OOTOBER

Building Cars Live

BBC Two, dates TBC

CAR DESIGN HAS come a long way since the days of Henry 'any colour as long as it's black' Ford. But his assembly line technique – pioneered with the Model T – has successfully stood the test of time. Today's car factories use much the same method, with a brand new car zipping off a production line in Britain every 20 seconds.

Now, BBC Two is giving us the chance to go beneath the bonnet of the UK's car industry. James May, Kate Humble and Ant Anstead will broadcast two 90-minute episodes live from BMW's MINI plant in Oxford, the home of this most iconic of cars. The MINI plant is a hive of activity. Inside the body shop, 1,000 robots weld the cars into shape, with precision lasers

making sure that everything is perfectly aligned. In the paint shop, delicate ostrich feathers are used to remove any traces of dust before the paint is applied. Then it's time for assembly, where the sheer choice of various trims and finishes mean that there are more than one million billion possible combinations of MINI.

The show's presenters will also be visiting other UK car manufacturers, revealing how our industry is positively booming. Last year, Nissan's Sunderland plant built more cars than the whole of Italy combined; meanwhile the majority of Formula 1 teams are based in the UK. Not bad for a country that once churned out the Reliant Robin.



LISTEN

BBC RADIO PROGRAMMES

WITH JAMES LLOYD

TUESDAYS

Costing The Earth

BBC Radio 4, 3:30pm



Jheni Osman looks at urban gardens

THIS ENVIRONMENTAL SHOW returns for a new series. Highlights include former Focus editor Jheni Osman taking a look at urban gardens. With over 80 per cent of the UK's population living in urban areas, how can we 'greenify' our cities? Jheni reveals the species invading our backyards, and the gardening tips that will help them thrive.

23 SEPTEMBER

Mv Head

BBC World Service, time TBC

ON 30 JANUARY 2011, James Piercy was involved in a serious car crash and suffered a major brain injury. This is the story of his recovery. He meets the policeman who kept him breathing and the surgeon who operated in the dead of night. and finds out what injuries like his can tell us about the brain.

25-27 SEPTEMBER

Why Music?



Wildlife recordist Chris Watson in action

BBC RADIO 3 broadcasts live from London's Wellcome Collection with a smorgasbord of programmes exploring music's relationship with nature, memory and the mind. Why does music give us the tingles? And can music be used to treat mental illness?

28 SEPTEMBER

Natural History Heroes

BBC Radio 4, 1:45pm

SCIENTISTS AND CURATORS take us into the vaults of the Natural History Museum, introducing their personal heroes. The early pioneers of biology, palaeontology and botany were prolific collectors, going in search of bones. animals, plants, and pretty much anything they could get their hands on.

ONLINE

FutureProofing



have in store? Unfortunately, crystal balls and horoscopes can't help us out there, but FutureProofing is the next best thing. In the latest series, Timandra Harkness and Leo Johnson (pictured) discuss the future of money, identity, life and food. Take that, Mystic Meg.



TOUCH

SMARTPHONE & TABLET APPS WITH KATE RUSSELL

LastOuake

iOS 6.0 or later, iPhone/iPad/iPod Touch, Android 2.3.3 or later, EMSC, free



DID THE EARTH just move for you? For a quick and easy way to confirm whether it was an earthquake, LastQuake's stark interface is designed to do just that. As well as using GPS to list reported quakes near you, you can reference significant tremors around the world and report anything going on in your area. Switch to the global map for a visual representation of the strength and reach of each earthquake, as reported by users tapping 'I felt that'. Behind the

headline information are even more details about the area that has been affected by the quake.

Solar Walk

iOS 7.0 or later, iPhone/iPad/iPod Touch, Android 4.0 or later, Vito Technology, £2.29/£1.82



TAKE A WALK through the Solar System, exploring high-resolution 3D images of the planets, asteroids, satellites and the star of the show - literally - our Sun. The app looks gorgeous, and includes links to information about the celestial bodies and their orbits and internal

structure. It certainly makes a great introduction to astronomy. There's a free version of Solar Walk if you want to get a feel for it, but it has hardly any content unlocked and the in-app purchases mean that you will probably be better off downloading the unlocked, premium version.

Netter's Anatomy Atlas Free

iOS 3.2 or later, iPad, Elsevier, free



FRANK H NETTER was a surgeon who became known for his medical illustrations, and now you can enjoy his work through the Netter's Anatomy Atlas iPad app. The free version has a sample of 14 detailed drawings of the human body, complete with linked label plates that provide a great reference tool for medical professionals and interested amateurs alike. Interactive elements, including customisable labels, a search tool and a guiz are a nice addition to the app. You

can purchase the full version for £69.99.

KATE RUSSELL is a technology journalist and Click presenter



24 SEPTEMBER

Solar Secrets: Understanding Our Star, The Sun

Royal Observatory Greenwich, London, 7pm-8:30pm, £7, rmg.co.uk

AT THIS TALK, journey into the heart of our Solar System and explore how far we've come in our understanding of the Sun.

30 SEPTEMBER

Rolls-Royce's Engineering At Work Day

Thinktank, Birmingham, free, bit.ly/1PnIA89

STUDENTS IN YEARS 8 and 9 can get hands-on at these workshops run by Rolls-Royce engineers. Booking essential.



FROM 9 OCTOBER

The Crime Museum Uncovered

Museum of London, from £10, museumoflondon.org.uk

NEVER-SEEN-BEFORE objects from the Metropolitan Police's Crime Museum are now on public view.



13 OCTORER

Rosetta - The Story So Far

Royal Astronomical Society, London, 1pm-2pm, 6pm-7pm, free, ras.org.uk

DISCOVER THE INCREDIBLE challenges of Rosetta at this talk by Prof Ian Wright, who was involved in the mission.

15 OCTOBER

I Am Because You Are

Royal Observatory Greenwich, London, 7pm-8:30pm, £8, rmg.co.uk

E=MC²IS SO simple, yet has become part of pop culture worldwide. Join astronomers and authors as they discuss an anthology of short stories and essays inspired by General Relativity.



FROM **15** OCTOBER

Wild World Tour

Various dates and venues, stevebackshall.com/tour.php

DON'T MISS THE chance to hear more of Steve Backshall's adventures at one of his talks at various venues across the country, running until 15 November. Check prices online.



25-27 SEPTEMBER

Why Music?

Wellcome Collection, London, free, wellcomecollection, org

AT THIS UNIQUE weekend, BBC Radio 3 and the Wellcome Collection host leading musicians and big names in neuroscience, music therapy and music psychology. Among the highlights: Prof Marcus du Sautoy on the maths of music, actor Griff Rhys Jones explores Wellcome Collection objects, pianist James Rhodes discusses music and mental illness, presenter Tom Service examines how music influenced our evolutionary development, and psychologist Lauren Stewart and composer and pianist Neil Brand explore what it is about music that sends a shiver down our spine.

FROM 22 OCTOBER

Manchester Science Festival

Various venues, manchestersciencefestival.com

COMEDY, THEATRE, TALKS, music, film, experiments and exhibitions all merge at this festival, which runs until 1 November. Plus, there's an adult-only ball pool! Check prices online.



HATH 4 NOVEMBER

Secret: Nothing To See Here

Science Gallery, Dublin, free, dublin.sciencegallery.com

BY DELVING INTO the technology and psychology of keeping secrets, this exhibition reveals how hackers, spies, journalists, criminals and governments tackle the hush-hush world.



IINTII 8 DECEMBER

Just For Graphs

Various dates and venues, festivalofthespokennerd.com

UNASHAMEDLY GEEKY? THEN you'll love this live comedy show, running until 8 December. Check prices online.



💷 Hardback 🥦 Paperback

The Evolution Of Everything

Matt Ridley
4th Estate \$\omega\$ £20

THOUGH I'VE NEVER met him, I feel like I know Matt Ridley pretty well. My first interaction with him was back in the mid-1980s, when he was the wunderkind science editor of *The Economist*. I'd ring him up whenever I thought I had a piece he'd print, and soon twigged my chances were greatly enhanced by having some contrarian line about a controversial issue widely believed to have an 'obvious' solution. Simples.

Actually, it wasn't. I soon realised how hard it is to free oneself from conventional thinking, and spot flaws in what everyone 'knows' is the right answer. But blowing up sacred cows comes naturally to Ridley, and he went on to build an award-winning writing career out of it. Originally trained as a zoologist, he's made a speciality of exploring the wider implications of Darwinian evolution. Now he's combined his two passions with his most ambitious book to date, in which he seeks to do "for every aspect of the human world a little bit of what Charles Darwin did for biology".

Specifically, he wants us to see past the view that our world is replete with the results of human intention, and notice instead how so much has simply evolved into being.

"I came away enlightened, challenged, and somewhat in awe of an author able to write so lucidly" THE EVOLUTION OF the Universe morutiry Life Genes Callare THE ECONOMY TECHNOLOGY the mind Pensonality Education Population SIMERSHIP GOVERNMENT Religion MÖNEY the internet **EVERYTHING** MATT RIDLEY

To do this, Ridley moves beyond what he describes as the 'Special Theory of Evolution' to the 'General Theory'. According to this, the processes of random events, trial and error and cross-fertilisation that are normally associated with the natural world also explain much that is held to be the product of human intervention.

Those who bracket evolution with 'nature, red in tooth and claw' might be expecting the result to be an explanation of why the world is so awful. But here Ridley plays his contrarian card. Through a host of examples in fields ranging from psychology and technology to politics and finance, he makes the case that – broadly speaking – the world is evolving into a better state despite human intervention, rather than because of it.

Or at least, he attempts to. While I'm sympathetic to Ridley's aim and his conclusion, much of his evidence feels handpicked or partial. His free-market zeal also breaks through his claims a little too often for my liking. Even so, I came away enlightened, challenged, and somewhat in awe of an author able to write so lucidly about so much.

ROBERT MATTHEWS is Visiting Professor in Science at Aston University



EET THE AUTHOR

Matt Ridley

What's the idea behind your book?

It's that evolution – incremental, gradual selective change that produces complexity and order without a plan – is something that applies to much more than just biological systems. It explains how language evolves, and how society and technology changes.

How does technology evolve?

If you look at how new technologies emerge, we give far too much credit to inventors. Twenty-three people independently came up with the idea of the incandescent light bulb – it was the next inevitable step based on what had happened before. There are lots of ideas out there: some get chosen, some get dropped and the result is an incremental change in technology.

You also say that morality is an evolutionary process...

I argue that the idea of evolution pre-dates Darwin, and is really an Adam Smith idea. His 1759 book *The Theory Of Moral Sentiments* says that morality evolves because people calibrate their actions against other people's reactions. Morality emerges from below rather than being forced down our throats from above. If you look at the history of morality, priests and teachers are actually catching up with what people are saying – that's still very clear today with things like the toleration of homosexuality.

What can this tell us about the world?

There's a long tradition of trying to look for the causes of things and define who achieved what. But there's another tradition that got buried, which says that these things emerge. There is order and complexity in the world, but it doesn't need an orderer or a complexifier. To me, that's one of the most wonderful ideas.



Four Ways To Click

Rewire Your Brain For Stronger, More Rewarding Relationships

Dr Amy Banks with Leigh Ann Hirschman
Allen & Unwin P £14.99

THIS BOOK ARGUES that human relationships are vital for good health and are the product of four dedicated brain areas. This allows you to 'rewire' your brain to improve relationships. As a neuroscientist, this sets off alarm bells.

Despite being an often engaging read with supposedly laudable aims, Four Ways To Click seems deeply cynical. Brain regions of frightening diversity are cast as being for relationships only, and claims are 'backed up' with neuroscientific findings as if they're proof, rather than complex and uncertain properties of the brain still subject to much research.

Alarmingly, much time is dedicated to stressing the importance of human relationships, only for them to then be reduced to little more than basic behaviours. It's apparently a simple matter of doing certain actions to make your brain better at relationships, like rearranging a room to get more space.

Early in this book, it says that human relationships are highly complex and not a simple process produced by a select few brain regions. Depressingly, the rest of the book assumes the exact opposite.

DEAN BURNETT is a neuroscientist who lectures at Cardiff University



Why Does Asparagus Make Your Wee Smell?

And 57 Other Curious Food And Drink Questions

Andy Brunning

Orion Books 💷 £12.99

LET'S GET THE spoiler out of the way first: thiols are what asparagus is broken down into when we digest it. But did you know these compounds are also found in skunk spray? And that not everyone produces asparagus-stinky urine? (In fact, 43 per cent of people do.)

It's these sorts of questions that Andy Brunning aims to answer. Using that ever-popular topic of food and drink, Brunning offers an entertaining insight into the real chemical reactions behind everyday mysteries, like why bacon smells so good, and why coriander tastes soapy. Each chapter offers a clear explanation with quirky factoids and colourful infographics. But some chapters are bogged down with chemical names more than others, and the infographics are not always enlightening. Many just parrot the text, rather than adding any particularly new insight.

Why Does Asparagus Make Your Wee Smell? is a solid coffee table book to flick through. It's not going to change your world, but it'll definitely make you think next time you're in the kitchen.

MUN-KEAT LOOI is a science writer and co-author of *The Big Questions In Science*



The Shark And The Albatross

Travels With A Camera To The Ends Of The Earth

John Aitchison

Profile Books £17.99

HIGH ON THE list of enviable career paths is that of the wildlife cameraman. What other profession takes you to so many exotic locations and offers a front row seat for the world's greatest natural wonders? Few are better placed to explain the challenges of filming animals in the wild than John Aitchison, who for 20 years has travelled to every continent, for series such as the BBC's Frozen Planet and Life Story.

As a straight travelogue, *The Shark* And The Albatross feels a little disjointed. But at its best, it explains what goes into capturing very specific scenes in incredibly harsh environments. For example, there is the trip to Svalbard where Aitchison struggles with the need to carry a gun in case the polar bears he's come to film turn on him, and his negotiations with Chinese bureaucrats to film Siberian cranes. Aitchison excels at highlighting the lives of animals and explaining the conservation challenges they face, whether it's the sharks and albatross that give the book its title, or penguins, tigers and the elusive Canadian lynx. A must-read for fans of the BBC's natural history programming.

MATT SWAINE is editor of *BBC Wildlife* and previously worked at *Lonely Planet*



13.8

The Most Important Fact In The Search For The Theory Of Everything

John Gribbin

Icon Books 9 £16.99

CARDS ON THE table: I'm a John Gribbin fan. His books helped inspire me to study physics.

So I was excited to read his latest offering – 13.8: The Most Important Fact In The Search For The Theory Of Everything. The '13.8' refers to our Universe's age in billions of years, and much room is given to the question of whether it had an origin at all. With much historical colour, Gribbin recounts the fight between the Steady State and Big Bang models. This is followed by details of the cosmological chiselling that led to modern calculations of its age.

While these parts are great, I can't help but feel a little let down. The blurb and

subtitle promise a book on how this quest for the Universe's true age is the key to the Holy Grail of physics – a 'theory of everything' – that combines General Relativity and quantum theory. After some introductory passages explaining how quantum theory accounts for how stars are powered, and how long they shine, the 'Holy Grail' is never mentioned again. This, unfortunately, makes the claim that this is a landmark book more than a little hollow.

COLIN STUART is a science writer and co-author of The Big Questions In Science

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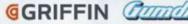
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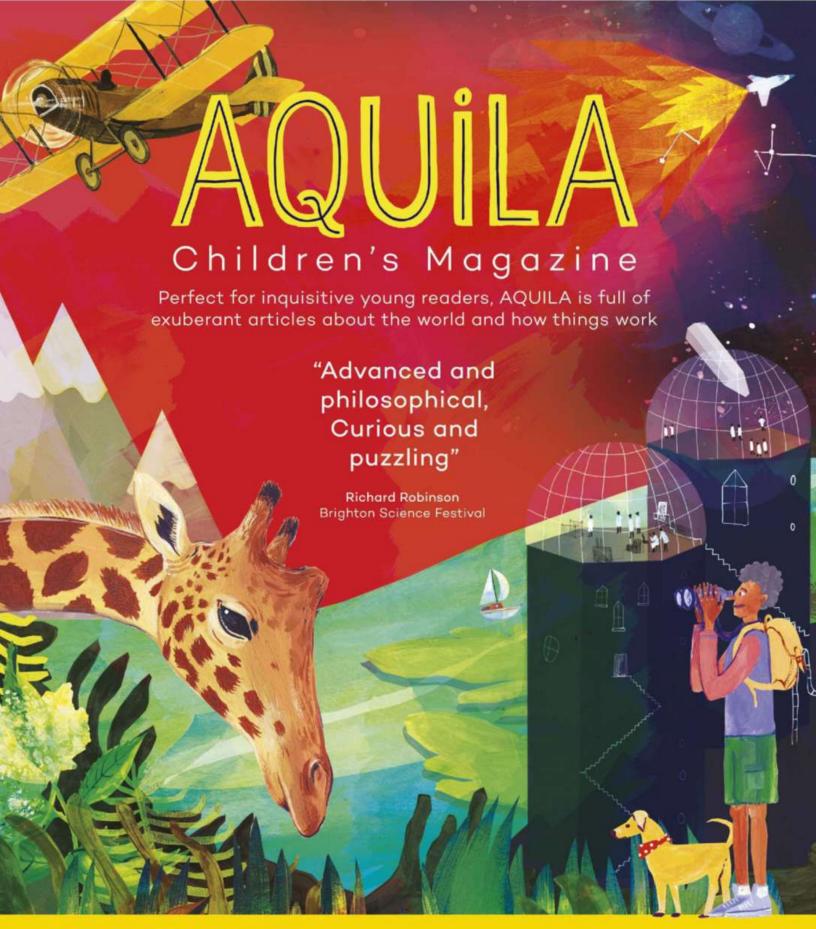
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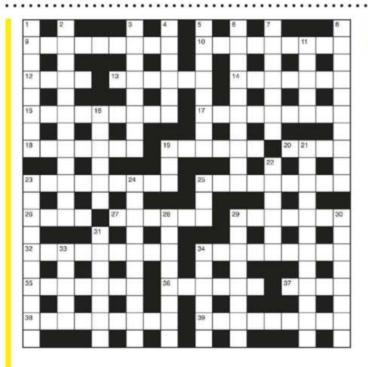
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FOCUS CROSSWORD No 182

Moreonline Solve puzzles from BBC Only Connect hosted by Victoria Coren Mitchell at http://bbc.in/1vCOzuY



ACROSS

- Tot's crib shook with energy of childbirth (9)
- Respond with use of cane, meeting resistance (9)
- European copper has right colour (4)
- 13 I like an ice cream to be symbolic (6)
- I can't work with no radioisotope (7)
- Raise plot using clay deposit (9) Soldier in suitable American machine (9)
- Hail old information it leaves one cold (7)
- Mr Henry pursues British fish (6)
- 20 The brook goes round the river (4) 23 Greek character in unusual toenail
- and hair removal (9)
- 25 Worry about bumpkin finding eastern squirrel (9)
- 26 Collapsed round part of church (4)
- 27 Register for a large drink (6)
- 29 A novice to object to part of Icelandic politics (7)
- 32 A termite's affecting temperature gauge (9)
- Sprinkling huge pips round my head causes skin condition (9)
- 35 Bother to play old instrument (7)
- 36 Turn stomach over with the French accent (6)
- Supporter of foul nature (4)
- 38 Large hoop displayed in oil print (9)
- 39 Article knocks identification of extinct reptile (9)

DOWN

- In favour, since working for the law (8)
- Scary sophist reinvented science (12)
- Spinal treatment, being thrown into cart (8)
- Cake gets caught on bracket (6)
- Couple take in feline with feathered legs (8)
- April wind swirling round a city (10)
- Figure it has right height (7)
- It's one solution manage optical device (10)
- Group transported tonne (5)
- Only great recipe for a drink (6)
- 19 He's big in Scotland (3)
- Yearning to get German girl a lens (7,5)
- 22 Draw small boat (6)
- 23 Delight in seeing some larks (10)
- 24 Inconsistent as a number (10
- 25 Copper gets point of signal (3)
- 28 Carriage uncovered with painful sound (8)
- 29 Affair gets republican journalist toughened (8)
- 30 Aged soul performed for composer (8)
- Vespucci's first inspiration for country's name (7)
- 33 Scandinavian food (5)
- 34 Dish has a taste (6)

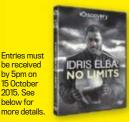
SOLUTION TO CROSSWORD No 179

P Glendinning, Barry Gordon, Margaret Baxter, Donald Kennedy and Ivor Dibble each correctly solved issue 283's puzzle and receive a copy of Shark (BBC, £20.42).



WIN! IDRIS ELBA: **NO LIMITS**

The first five correct solutions drawn will each win a copy of Idris Elba: No Limits (Go Entertain, £9.99). Entries must be received by 5pm on 15 October 2015. See below for more details.



by 5pm on 15 October

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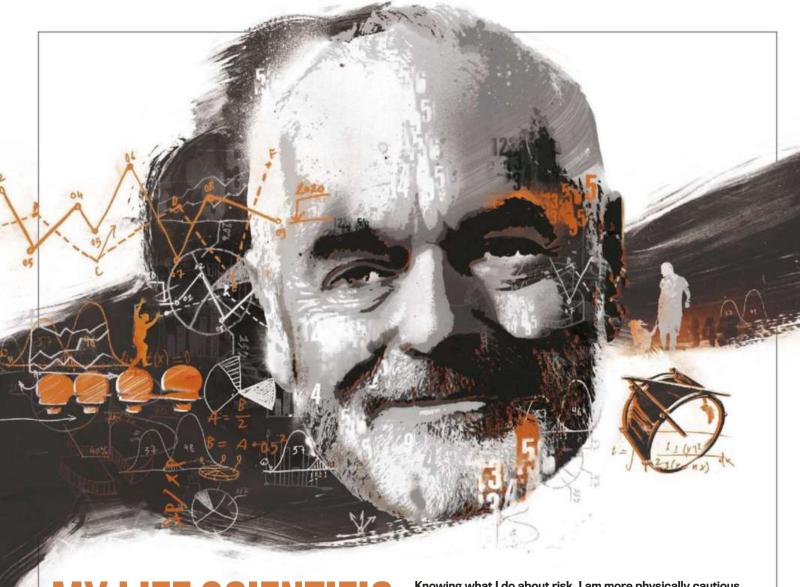
EMAIL

Post entries to BBC Focus Magazine, October 2015 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to october 2015@focuscomps.co.uk by 5pm on 15 October 2015. Entrants must supply name, address and phone number. Immediate Media, publisher of BBC Focus Magazine, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

TERMS & CONDITIONS

Entrants must be UK residents (inc Channel Islands) aged 18 or over. Immediate Media employees are not eligible to enter. By entering participants agree to be bound by these terms and conditions and that their name and county may be released if they win. Only one entry permitted per person. No responsibility is accepted for lost, delayed, ineligible or fraudulent entries. Entries received after the closing date will not be considered. Immediate Media (publisher of BBC Focus Magazine) will only ever use personal details for the purposes of administering this competition unless

you permit otherwise. Read more about the Immediate Privacy Policy at www.immediatemedia.co.uk/privacy-policy. The winning entrants will be the first correct entries drawn at random after the closing time. The prize and number of winners will be as shown above. The winners will be notified within 30 days of the closing date by post. Immediate Media's decision is final and no further correspondence relating to the competition will be entered into. If the winner cannot be contacted within one month of the closing date, Immediate Media reserves the right to offer the prize to a runner-up.



MY LIFE SCIENTIFIC DAVID SPIEGELHALTER

The UK's leading statistician tells Helen Pilcher why he's not very good at maths

I don't do maths. I'm not a good mathematician. But I do like using maths to handle numbers and data. I enjoy bringing order to chaos, looking for the signal in the noise, taking messy data and then extracting the structure from it. That's statistics, and it is fascinating because it provides a link between abstract mathematical thought and real world problems. Statistical modelling is used in everything from predicting football results to working out which drugs work – I've worked on both of these.

My biggest achievements include having over 70,000 citations on Google Scholar, which puts me in the top 10 in the world for statistics. For an academic, having piles of past publications is like a musician having an extensive back catalogue that they can live off.

But I'm also especially proud of my performance in an episode of *Winter Wipeout*. I was hopeless at the big red balls; in fact, I was hopeless at everything, to tell the truth. But I had studied the stats beforehand and so had trained to just keep moving for three minutes, and I ended up coming seventh.

Knowing what I do about risk, I am more physically cautious than I used to be. But I'm a creature of bad habits: I procrastinate, eat too much and don't exercise enough, so I try to change my lifestyle. Being reckless is idiotic but risk-taking can be wonderful. So I'm also bolder than I used to be, and I take more reputational risks. My latest book, *Sex By Numbers*, is a risk.

When I get the time, I play the surdo drum in a carnival band.

It's the big thump-thump thing that you hit with beaters. It's so loud that if you play it indoors it's a complete misery. In my downtime, I also like to go walking. I have a messy cocker spaniel called Daisy who comes with me.

People tell me statistics and probability are unintuitive and difficult. I've been working in the field for 40 years now and I've finally concluded that they're right. That's why it's important to explain it well. I was involved in public enquiries into children's heart surgery at Bristol Royal Infirmary and the murders by Harold Shipman. My main work now is translating risk into a form that people can understand, and it's great to have found something valuable to do.

I can't help feeling I have a strong case of Imposter Syndrome.

I'm very lucky as I've found my niche – statistics. But on the outside, I think people have an over-inflated view of my abilities; on the inside, I feel there's a lot of winging it going on! That said, I've only got a few

HELEN PILCHER is a science writer and comedian. She tweets from @Helenpilcher1

years to go before I retire, so I might just get away with it without being found out. ■



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